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REPORT OF THE SUBCOMMITTEE ON THE ECOLOGY OF MARINE ORGANISMS

HARRY S. LADD, Chairman

Presented at the Annual Meeting of the
Division of Geology and Geography
National Research Council

May 3, 1941

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WASHINGTON, D. C.

REPORT OF THE

SUBCOMMITTEE ON THE ECOLOGY OF MARINE ORGANISMS

* COMMITTEE ON GEOLOGIC RESEARCH

May 3, 1941

(Appendix A-1 of Annual Report
of the Division for 1940-1941)

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REPORT OF THE SUB-COMMITTEE ON THE ECOLOGY OF MARINE ORGANISMS

INTRODUCTION

The need for a sub-committee on the Ecology of Marine Organisms was recognized long ago by Dr. T. Wayland Vaughan, and it was largely through his efforts that the present group was formed. Organization of the Sub-Committee was completed in November of last year (1940), but, due to the Chairman's absence on a field assignment, a program of work was not initiated until January of this year (1941).

Ecology is a study of the relations of organisms to each other and to their environment. From this study, in the case of marine organisms, much is learned about the association of organisms in communities and their distribution with relation to depth, temperature, salinity, type of bottom, and other ecological factors. The paleontologist uses this information in attempting to reconstruct the probable organic environments of the past, as recorded in fossiliferous sedimentary rocks.

Much ecological and paleoecological work has been done, and a considerable amount is being carried on at the present time. In order to obtain as complete a picture as possible of current and recently completed activities, the Sub-Committee has made a canvass of individuals and institutions interested in these subjects. Results are summarized in the body of the present report.

In assembling this information the committee members have tried to confine their attention to ecological researches that may have some bearing on paleontology and be of assistance in making geological interpretations. The general field of the ecology of marine organisms is so broad that it would be presumptious for a committee composed largely of geologists to attempt to make an adequate survey of all activities. Indeed, it would seem that our Sub-Committee is misnamed, because its title suggests this broad field. A longer title such as the "Ecology of Marine Organisms with reference to Paleontology" would be more awkward but more accurate.

During the coming year the Sub-Committee hopes to obtain a more complete picture of current activities. Aims for future work will include attempts to stimulate and promote needed types of ecological investigations; possibly still later the preparation of a special treatise on ecology that would stress geological interpretation. It has been suggested that owing to the prevalence of nonmarine sediments, especially in the Tertiary, it might be desirable to enlarge the scope of the Sub-Committee to include the ecology of land and fresh water organisms as an aid in interpreting nonmarine sediments.

THE SIGNIFICANCE OF FOSSIL ASSEMBLAGES

This being the first report of the Sub-Committee it will perhaps be appropriate to discuss briefly some of the general problems that confront the ecologist and paleoecologist and to consider in particular the attitude of geologists and paleontologists toward the ever-increasing amount of work being done in these two closely related fields.

Many of the earliest investigators of marine ecology were primarily collectors. They combed the tidal flats of modern shores and dredged the ocean bottoms, but, aside from noting depths and types of bottom, they paid little attention to the relations of the organisms to their environment and to each other. Many early paleoecologists were likewise content to collect fossils and to make generalizations regarding probable depths and types of bottom. Later, the ecologists began to make more critical studies, and consideration was given to other ecological factors including temperature, salinity, circulation, light, food supply. Associations of organisms were visualized as communities composed of various types of individuals all dependent upon each other as well as upon their physical environment. The paleoecologist, following in the wake of the students of living organisms, began to study fossil assemblages more carefully and to realize clearly that differences between some fossil assemblages might reflect differences in environment rather than differences in geological age.

As all students of ecology will admit, it is not easy to obtain a true picture of any sort of a community of marine organisms and, as will be shown later, the paleoecologist labors under additional handicaps. Consider, for example, an attempt on the part of an ecologist to study an intertidal community that lives in an area made easily accessible twice daily by the retreating tide. At first glance this would seem a comparatively simple task. After reconnoitering the shore the ecologist is able to select a typical area for intensive study. In this restricted area he can list the inhabitants and determine their distribution relative to tide levels, type of bottom, and available food. He can record the temperature of the water and its chemical composition, including salinity, available oxygen, probable pH, etc. He becomes familiar with the movements of the water, and by studying the life histories of the members of the community he learns much about their relations to each other. Yet with all this he has not obtained a complete picture of the life of that particular community, for most of his observations must of necessity be made when the tide is out during the daylight hours. The conditions that he sees may be quite different from those that exist when the tide is high or during the hours of darkness. Likewise, conditions vary during different parts of the year when seasonal migrations may alter the make-up of the community considerably.

The ecologist who elects to study communities that live below the tidal zones has some problems of a different sort. In exceedingly shallow waters he may explore the sea bottom with some sort of diving apparatus, but in greater depths he must depend almost entirely on samples dredged from the bottom. Intensive work of this type will give a fair picture, but some of the animals in the community lie buried as much as a foot below the surface and most dredges do not recover these forms.

However, in spite of these various difficulties, the ecologists by series of detailed studies are obtaining much information about a variety of existing marine communities, particularly in the various near-shore environments. These studies contain a wealth of detail, but much of this has little interest for the paleoecologist at the present time. Later, when the growing mass of detail is more nearly complete, it may be digested and summarized, yielding principles that the paleoecologist can apply to his studies of ancient faunas and floras.

At the present time the paleoecologist labors under handicaps that do not trouble the student of existing communities. In fact, these handicaps are so great that some paleontologists propose to dismiss the whole study of paleoecology with a wave of the hand. They are, it seems unduly impressed by the fact that fossil assemblages are often mixed. They doubt the ability of the paleontologist to separate the foreign elements and determine which of the species originally lived together, and which were carried in from some other environment after death. Fortunately, the number of paleontologists who hold this extreme view is small.

On the other extreme, there are paleontologists who see no real difficulty in separating the elements of a mixed assemblage. This group likewise is small. Most paleontologists are well aware of the difficulties that beset the paleoecologist. They recognize that in some few cases the paleontologist can be certain that he is dealing with organisms that died in their natural environment. In other cases he can be equally sure that certain foreign elements have been introduced. He also recognizes that in studying most fossil assemblages the paleontologist cannot be certain of his interpretations. He must proceed cautiously and conclude with an opinion as to the ecological conditions under which a given fossil assemblage lived.

A few specific examples may be used to illustrate these several cases. When a paleontologist finds the shells of attached mollusks such as Ostrea and Chama in normal position with both valves in place on a rocky foundation he may be certain that the animals lived and died in that position. The same interpretation may be applied to certain types of fossil reef corals. If long branching colonies of Acropora are found upright on their narrow bases he may be sure that they have not been brought in. In the case of more massive colonies the task is not so easy, unless an overwhelming proportion of the colonies are in position of

growth. If boring pholads are found upright in pockets of sand it seems clear that the clams died in their natural habitat. Other borers found in coral heads may be in place, but the coral heads may have been transported.

When, on the other hand, a deposit contains only the lighter upper valves of an attached species such as Chama it can be confidently stated that these lighter valves were transported to their final resting place.

Other criteria are suggestive, but less conclusive. Shells, for example, that are badly worn may have been carried considerable distances but may, on the other hand, merely have been rolled about considerably on the home grounds before being finally buried in the accumulating sediments. The occurrence of attached valves of weakly hinged species suggests that such clams were buried close to their place of abode. Likewise, the preservation of delicate spines and similar processes on certain types of brachiopods and gastropods suggests that these forms were quickly buried following death. The occurrence of numerous examples of both adult and adolescent forms of a given species in the same deposit is suggestive but does not constitute proof of prompt burial. The occurrence of a few land or fresh water shells in an assemblage that is dominantly marine indicates fairly clearly that the former have been carried in, particularly if the nonmarine shells are broken or worn. The occurrence of intertidal species together with forms from deeper waters are cases that require special study. In many instances the shallow water species may have been carried to deeper water, but if they greatly outnumber the deeper water species it may be more reasonable to assume that storm waves carried the deeper water forms into the tidal zone.

The mixing of forms that is recognized in many fossil assemblages may be caused by one or more geological agents. Waves and currents in the sea are probably the most active agents. They may carry dead shells or other skeletal parts for considerable distances. Such transportation may be facilitated if the parts moved are shells that contain air chambers or if the organism is buoyed up by gases of decomposition. Streams bring many land and fresh water shells to the sea, and under proper conditions the wind also acts as a transporting agent. Organic materials may also be rafted by floating ice or floating vegetation.

There is need for much additional information on the extent to which waves and currents and other agents actually transport shells today. Studies should be made comparing the distribution of the living organisms with the distribution of their hard parts in sediments that are now accumulating.

In addition to the mixing of species the paleoecologist has a second major difficulty that rarely plagues the student of living organisms. In most cases the paleoecologist has available for study only a small percentage of the entire community. Many organisms leave no record of their

existence, and of those that do leave a record the paleoecologist is able in many instances to collect only a small fraction.

In studying any fossil assemblage the paleoecologist must first eliminate the elements that obviously are foreign, and then carefully consider the forms that remain, making comparisons with the nearest relatives known from existing seas. In dealing with the more ancient assemblages, particularly with organic groups that have no close living relatives, the difficulties are enormously increased, and all interpretations are subject to qualification. In studying the paleoecology of such long extinct groups some insight into the habits of the organisms can be gained by considering the form and structure of the fossils. Students of extinct types of echinoderms, brachiopods, and cephalopods have done considerable ecological work of this type.

CURRENT ACTIVITIES OF INTEREST TO GEOLOGISTS

Before discussing current activities in ecology and paleoecology it appears desirable to call special attention to several fairly recent publications in these fields. First are the two mimeographed reports issued in 1936 and 1937 by the Committee on Paleoecology, W. H. Twenhofel, Chairman, Division of Geology and Geography, National Research Council. These two reports contain nine articles giving a great deal of very valuable paleoecological material. More recently T. Wayland Vaughan, in his address as retiring President of the Geological Society of America, gave a general survey of the field and described a series of recent ecological researches of particular interest to geologists. (Ecology of Modern Marine Organisms with reference to Paleogeography, Bull. Geol. Soc. Amer., vol. 51, pp. 433-468, 1940). None of the papers cited in the reports of the Committee on Paleoecology or referred to by Vaughan are included in the present report. The Sub-Committee has attempted as broad a survey as somewhat limited time would permit, but it is very probable that a number of important projects and publications have been overlooked. If such cases are called to the attention of the Sub-Committee they will be included in next year's report.

EASTERN UNITED STATES

Woods Hole Oceanographic Institution

Mr. H. C. Stetson of the Museum of Comparative Zoology at Harvard and of the Woods Hole Oceanographic Institution has been working on cores from great depths. As a member of the Sub-Committee he has submitted four reports dealing with the work of his colleagues, as follows:

Ecology of marine phytoplankton by Bostwick H. Ketchum. - Several members of the staff of the Woods Hole Oceanographic Institution have been investigating problems pertaining to the ecology of marine diatoms and other phytoplankton during recent years. Dr. Henry B. Bigelow, Dr. Lois Lillick, and Dr. Mary Sears have recently completed an annual survey of the distribution of the phytoplankton in the Gulf of Maine. The factors affecting the distribution received particular attention. The analysis of the species of diatoms found at different seasons shows that certain species may dominate the population for a short while, after which they decline and other species predominate.

An intensive survey of the plankton population on Georges Bank is now being made. This region is of great importance since it comprises one of the large commercial fisheries on the eastern coast. Dr. Gordon Riley is conducting the phytoplankton studies for this project. The interest is primarily in the quantitative relationships between the phytoplankton and the different factors important in the growth of the plant cells. Intensive studies of the inter-relationship between the phytoplankton and chlorophyll, phosphate, nitrate, and oxygen are being made. At the same time Dr. George L. Clarke is collecting, by quantitative methods, the zooplankton and it is hoped that interesting inter-relationships between the two populations will be found.

The abundance and occurrence of the sedentary diatoms is being investigated by the department of microbiology in connection with studies of the primary film which forms on surfaces submerged in the sea. Periodical collections are being made at a series of stations along the eastern coast, from Florida to Woods Hole, as well as at Bermuda. Although the primary film consists mainly of bacteria, it has been shown that diatoms frequently may make up a large proportion of the total film.

The investigation of the physiology of marine diatoms which was started several years ago by Dr. A. C. Redfield and Dr. B. H. Ketchum is being continued and has been extended to include other kinds of unicellular plant forms. A method for culturing unicellular plants in large quantities has been developed and many growth studies on different forms have been made. The influence of different proportions of nutrient supplies in the medium on the fat, carbohydrate, and protein constituents of the cells is being studied intensively.

Ecology of Foraminifera by Fred B. Phleger, Department of Geology, Amherst College. - Intensive work on the ecology of the Foraminifera has been in progress at the Woods Hole Oceanographic Institution since 1937. The material which has been studied consists entirely of the tests of dead animals contained in the marine sediments collected by Henry C. Stetson. The samples from which the Foraminifera have been obtained are of two general types: 1) bottom samples, mostly from the Continental Shelf, and 2) submarine cores, taken mostly from the Continental Slope. In studying the Foraminifera it has been assumed that the tests contained in each sample of sediment taken from the surface of the ocean bottom are representative of the fauna living at or above that place at the present time.

A quantitative study of the Continental Slope benthonic Foraminifera has demonstrated the existence of at least three general depth zones. The upper slope zone extends from about 200 meters to 600-1000 meters and is characterized by the relative abundance or presence of Cassidulinoides bradyi, Robulus, Bolivina subaenariensis, and Bolivina marginata. The middle slope zone from 600-1000 meters to 1600 meters is characterized by the relative abundance of Bulimina aculeata, Bulimina exilis, Angulogerina sp. 1, Virgulina squammosa, Bolivina subspiniscens, and Eponides wrighti. The deep slope zone, below 1600 meters, may contain Uvigerina peregrina and Bulimina inflata in abundance. The zone from 600 to 1000 meters depth is a transitional depth zone having overlap ranges of several species typical of both the upper and middle zones, and this transitional zone is difficult, if not impossible to identify at the present time. This last zone, which appears to be a critical one in vertical distribution of Foraminifera, is the depth zone in which the bottom temperature is mostly 4 degrees C. or less. It also coincides roughly with a general zone of minimum oxygen concentration, but this may be an accidental correlation. It appears probable that temperature variation may be a critical factor in influencing this apparent depth distribution, but this cannot be demonstrated at the present time. It can be demonstrated that these zones hold for the region from Georges Bank to Chesapeake Bay and are not due to variations in geographic distribution.

The actual depth limits indicated above are in reality a zone of one or more hundred meters and are not sharp boundaries. These distributions on the Continental Slope are based upon about 60 surface samples and are therefore tentative until additional material is collected and studied. The recognition of these tentative zones is on the basis of relative quantitative species occurrence; frequency curves showing this distribution will be published in the near future. The zones are not easy to recognize.

Several problems have been raised by the work on the submarine cores from the western North Atlantic. It has been assumed that the pelagic forms listed by Brady, Cushman, and others are in all cases strictly pelagic species and that all other species are benthonic. It has been further assumed, by many people at least, that these pelagic Foraminifera are more

or less restricted to the surface layers of the ocean. Differences of shell structure of various globigerinids, from the same sample in many cases, have suggested the possibility that different habitats for the same species are indicated. Faunal distribution from the cores have suggested the possibility that some benthonic species are in part pelagic.

It is now obvious that more information must be obtained on living Foraminifera, since practically nothing is known. During the season of 1940 a practical method for collecting and preserving living pelagic Foraminifera was used with success. It is proposed to begin systematic quantitative collecting of living pelagic Foraminifera and this will be begun during the 1941 season. These collections will be made from all depths over as large an area as future time and facilities permit. It is also desirable to make certain experimental studies on living Foraminifera; some of these are food habits, temperature ranges, salinity range, oxygen consumption, etc. The biological researches are a necessity if we are to understand the relationship of these animals to their environment, and therefore to interpret the significance of faunas occurring in the bottom sediments or in marine rocks deposited in the geologic past. The collection and study of the Foraminifera from the cores will continue, but solution of many of the problems presented will depend upon the results obtained from the study of the vertical and geographic distribution and the physiology of the living animals.

Foraminifera of the East Coast Continental Shelf. - Dr. Joseph A. Cushman and Miss Frances L. Parker are making a quantitative study of the Foraminifera of the east coast Continental Shelf from Cape Cod to Cape Canaveral. The samples were taken by the Woods Hole Oceanographic Institution for a study of the sedimentary conditions of this same area. They are spaced one half to one mile apart and were collected in eight traverses which begin in most cases near the beach and continue beyond the break in slope. Dr. Cushman has the section south of Cape Hatteras, and Miss Parker, who has been working at Woods Hole, has taken the northern section. The purpose of the study is to establish relationships of the different genera and species and the ecologic control that temperature and depth exert over them. Because the temperature ranges involved are large it is hoped that when completed this study can serve as a sort of yardstick in the more exact interpretation of cores taken in deep water farther down the slope and from the ocean basin.

Evidence has been found for several ecologic zones running parallel to the coast. Faunal differences have also been established for the different sections of the shelf. The Foraminifera from each station have been counted and their relationship by percentage and abundance worked out in order to give as precise data as possible.

Factors underlying the productivity of Georges Bank by George L. Clarke. - An investigation has been begun of the steps in the biological cycle which underlie the productivity of a fishing area off Cape Cod known as Georges Bank. The yield of commercial fish from this area, which is larger in size than the state of Massachusetts, is valued at three to nine million dollars annually.

The first step in the constructive part of the food cycle in this area, as in most situations, must be the photosynthetic activity of green plants. Photographs of the bottom and other evidence has shown, however, that there are few if any fixed plants growing on the bank. The basic organic synthesis must therefore be performed by the pelagic phytoplankton of which the diatoms are the most important. Although a slim population of diatoms is to be found in the waters of the bank at all seasons, these plant producers are really abundant for only short periods during the year most notably in April. The next step in the upbuilding part of the food cycle is represented by the copepod group. However, these animals first show the greatest growth and attain the highest numbers in May and June and continue to be abundant along with other elements of the zooplankton for the remainder of the year. Our first problem then, is to discover through what means, physical or biological, the production of diatoms in short periods becomes available for the copepod group in other months of the year.

Our second main problem is to ascertain in just what way the organic matter which is apparently first to be found in the animals of the plankton becomes transferred to the sea bottom where it can be used by the benthonic animals. This step is important because the majority of commercial fish on Georges Bank are chiefly bottom feeders. There follows also the need for an investigation of the distribution of the bottom fauna both as to kind and as to quantity, and its variation from season to season and from year to year.

The foregoing steps in the biological cycle are being investigated, first, by means of quantitative measurements of the different categories of life all over the bank at different seasons. This is accomplished by visiting a network of stations over the bank at frequent intervals and taking samples of water, making net hauls, and dredging. Second, the food requirements, rate of growth, and general interdependence of the important organisms on the bank are being tested. Third, the influence of hydrographic features - particularly temperature and currents - on the growth and distribution of the plants and animals involved is being worked out.

A final problem, also under consideration, is the dependence upon this main biological cycle of the production of eggs and the growth of the young of the haddock, which is the most important of the commercial fish. The distribution of the haddock during its pelagic stage is dependent upon the currents and the growth of the fry is dependent upon the provision of a suitable but changing food supply first from the plankton and later from

the bottom. When the normal course of interdependencies of the haddock and the environmental factors of the bank - both physical and biological - have been worked out, we should then be in a position to find the causes of the annual fluctuations in the abundance of the haddock. These fluctuations are not only of considerable biological interest but of great commercial importance as well.

To Dr. Clarke's report Mr. Stetson adds the following:

"He is planning to undertake a quantitative survey of the bottom living invertebrates of Georges Bank by means of a specially constructed dredge which scoops up a measured quantity of the bottom. This is the first time that any such quantitative survey has been projected since C. G. J. Petersen made his classical studies of the bottom populations in the shallow sounds of the Baltic."

Individual Reports

Dr. Paul S. Galtsoff, who is in charge of shellfisheries investigations in the U. S. Fish and Wildlife Service, has completed a report on "Oyster Investigations in Maine" which has some bearing on paleoecological problems.

Dr. A. E. Hopkins, Dirctor of the recently established Fisheries Biolo ical Laboratory, U. S. Fish and Wildlife Service, located at Pensacola, Florida, has initiated a program dealing with the physiology and ecology of the entire coastal region near the laboratory where oysters are produced. Since the closing of the Tortugas Laboratory this is the only biological laboratory on the Gulf Coast.

Dr. Louise M. Perry of Sanibel Island, Florida, is at work on a paper dealing with the marine ecology of the Sanibel area but results will not be ready for press for some time.

Dr. Herbert F. Prytherch, Director of the U. S. Fishery Biological Laboratory at Beaufort, N. C., reports that his laboratory and the Duke Marine Laboratory are conducting a variety of investigations dealing with marine animals and plants but that the efforts of the U. S. Laboratory are devoted primarily to problems dealing with the maintenance and utilization of the fishery resources of the South Atlantic region.

Dr. Horace G. Richards of the Academy of Natural Sciences of Philadelphia has submitted the following summary of his work on paleoecology:

"Pleistocene. During the past few years I have had the opportunity of collecting Pleistocene from various localities along the Atlantic and Gulf Coast. Attention was paid to the ecology, particularly the climatic conditions, indicated by the fossils. I am now engaged in preparing an

illustrated catalogue of the Pleistocene marine fossils of the Atlantic and Gulf Coast. When and if this is published, there will be discussions of the ecological conditions indicated by the fossils.

"During the summer of 1940, I collected Pleistocene fossils from several localities along the West Coast of Hudson Bay and from Baker Lake, N.W.T., Canada. In a report to be submitted this month [March] to the Academy of Natural Sciences, there is a discussion of the water temperature and ecological conditions indicated by the fossils.

"Miocene. In collaboration with Miss Anne Harbison, I have been making a restudy of the fauna of the Miocene of New Jersey. The Kirkwood formation has been shown to consist of several phases. The temperatures, depth of water, and other ecological conditions under which the various faunules lived are to be discussed."

MIDDLE UNITED STATES

Dr. Kenneth Caster of the University of Cincinnati is much interested in the ichnology of the chelicerate arthropods and other fossil tracks and burrows; he has also been working recently on environmental data of the Hexactinellid sponges, past and present.

Mr. Thomas Payne at the University of Chicago, according to Professor Carey Croneis, is preparing a thesis on Middle Devonian in which paleoecology plays a rather significant part.

Dr. Rousseau H. Flower, Curator of the Geological Museum at the University of Cincinnati, is investigating the environment of the Nautiloidea and has a considerable store of ecological material, largely new.

Mr. Gordon Gunter of the Game, Fish, and Oyster Commission of Texas who is stationed at Rockport, Texas, is carrying on hydrographic studies on Offatts Bayou at Galveston in connection with the recurrent summer death of oysters and other animal life there; he is also doing hydrographic work on Laguna Madre, a highly saline coastal lagoon. He is continuing his studies of the food of the porpoise and has in press an article dealing with the death of fishes due to cold on the Texas coast in January, 1940. In commenting on the advantages for certain types of ecological study possessed by the south Texas area where he is working Mr. Gunter says: ".... From the head of Copano Bay to the Gulf we have a relatively unchanging, estuarine area (because the tides are small and there are no large rivers near) with a stable salinity gradient from fresh water to sea water. There are all types of fish here, many that go from salt water to fresh water and the reverse, and I submit that there is not a better place in the world to study the relation of organisms to the salinity of their environment. The strategic position of this locality is enhanced by the oversalty Laguna

adre just to the south, with fish living in it under those conditions."

Professor Willis G. Hewatt of Texas Christian University is writing a report on the ecology of littoral and shallow water faunas of Santa Cruz Island, California. The work will probably be finished in the very near future.

H. S. Ladd of the U. S. Geological Survey is studying fossils obtained from shallow wells along the Texas coast and comparing them with the faunas that inhabit the coastal waters today. During the past two years the U. S. Geological Survey has cooperated with the State Board of Water Engineers of Texas in an investigation of ground water resources of the state. Using W. P.A. funds, a large number of shallow wells were put down along the Gulf coast in Aransas, San Patricio, and Calhoun Counties. Most of the wells are arranged in a series parallel to the coast, with a lesser number in lines at right angles to the coast. None of the wells exceed 135 feet in depth. In most wells samples were taken every foot and a total of some 6,000 pounds was thus obtained. The wells penetrated a variety of sediments -- sands, clays, shell beds, "caliche". The beds are probably all Pleistocene in age, but this is not certain.

A preliminary survey has shown that a variety of rich shell beds are present in the upper part of the section and some of these, at least, appear to continue from well to well. The shell beds are best developed near the coast, becoming thinner to landward. In the lower part of the section Foraminifera are the commonest fossils. A series of samples has been examined for diatoms, but none have been found as yet.

Collections of Recent mollusks were made along the Gulf shore and in the coastal bays at numerous points from Matagorda Bay to the middle of Padre Island. Using launches furnished by the Game, Fish and Oyster Commission of Texas and the U. S. Fish and Wildlife Service, dredging and bottom sampling operations were carried on from the mouth of the Guadalupe River to the open Gulf off Aransas Pass. Elevated oyster reefs, caliche pits, etc., in various parts of the area were also studied.

In the field a number of more or less distinct facies can be recognized in the Recent fauna -- from the nearly fresh waters close to the river mouths through the bays and passes to the open Gulf. It is certain that the Recent collections will be of much assistance in interpreting the well samples, and it is hoped that a study of the different facies will make more accurate age determinations possible.

Dr. W. Armstrong Price of Corpus Christi, Texas, is continuing his studies of elevated oyster reefs, other shell beds, caliche beds, and other features of the Corpus Christi area and is revising a comprehensive manuscript entitled "Pond Deposits of Pleistocene Offshore Bar, South Texas."

Regarding the shell deposits which are so numerous and varied on the south Texas coast Dr. Price states:

"..... it is possible to identify several types of beds ... which contain shells in the Quaternary of this coast ..... there are marine molluscs now close to sea level and Foraminifera and oyster beds up to 10 or 12 feet above sea level. There are also, seemingly at the same horizon and at the same elevation above sea, lenses of beach shell in positions which may have represented bay beaches located 10 miles inland from the inner shore of the offshore bar of the same age. In the floor of the old coastal lagoon between these above described, there are Foraminifera.....

"The historic and prehistoric Indians left great accumulations of shells along all bluffs overlooking tidewater and fresh water mollusc or land snail accumulations in inland sites. The bluff shell accumulations occur practically in every hundred yards of the coast of every tidal body of water from Matagorda Bay to the south shore of Corpus Christi Bay.

"To distinguish between the two types of deposits, where they are not mixed, ... is very easy after one has become familiar with the coast and its fossils. The Pleistocene shell beds are either always in a matrix of marl which is usually stained by greenish, yellowish, or tan clay and iron compounds, or, if cemented into a beach bed, they contain some gravel, and the cementation itself is limited to the pre-Recent deposits.

"The Indian shell deposits are either on the ground, in the deep soil of this coast (4.5 to 5 feet of black or brown prismatic clayey soil), or overlain by the distinctive clay-dune material or by sand dunes.

"When shells can be found in position of growth it is, of course, a definite criterion of Pleistocene age and undisturbed position. Indian accumulations frequently show burned shell, flint, baked clay, and charcoal, besides bones of human and animal skeletons. The latter are often cut or burned.

".....it is my belief that essentially non-edible and small shells may be found mixed with the Indian shell accumulations due to their known habit of carrying sack loads of shell from the bays to the bluffs to eat. It would seem quite possible that they got a mixture and picked out the edible individuals at the camp site. Also, Indian children are said to have played with small shells, pebbles, and other objects, which sometimes appear in the middens."

Mr. F. W. Rolshausen of the Humble Oil and Refining Co. has submitted the following "Preliminary Report on the Gulf of Mexico Samples":

"During 1939, through the courtesy of Rear Admiral L. O. Colbert, Director of the U. S. Coast and Geodetic Survey, approximately 130 samples

were obtained from the Gulf of Mexico. These samples were turned over to a committee appointed by the Houston Geologic Society and are now being studied as much as time and routine work will allow. After plotting the location of the samples ..... profiles were selected and slides of various organisms are being prepared.

"Mr. J. B. Garrett of the Stanolind Oil Company is working on the Ostracods, Mr. S. W. Lowman of the Shell Company - the grain size and heavy minerals, Mr. M. C. Israelsky of the Union Producing Company - the Foraminifera, and Dr. M. A. Hanna pelecypods and gastropods.

"Mr. Lowman of the Shell Company has completed his profile and has prepared a chart, showing tentative identification of the Foraminifera and their distribution with depth along one of the profiles.

"The other profiles are not complete, so no conclusions can be reported.

"We hope to be able to publish the complete report some time this year."

J. B. Garrett M. A. Hanna
M. C. Israelsky S. W. Lowman
F W. Rolshausen.

Henry V. Howe, Director of the Louisiana Geological Survey, states the following in a letter to Mr. Rolshausen:

"We have been very much interested in the Ecology of Marine Organisms but we have actually done very little work on this subject. As you know, Dr. R. Dana Russell has for some time been making a study of cores and grab samples from the Gulf of Mexico off the Louisiana coast. He has turned over the faunal content of a number of these samples to Mr. Lohman for study. We have also had an arrangement with the U. S. Bureau of Fisheries to obtain marine mollusca from them and a study of the mollusca of the Gulf of Mexico is at present going on under the direction of Dr. H. N. Fisk. The study is being made in conjunction with the Zoology Department here at the University. They have a remarkably fine collection of clams and snails and, of course, when the study is completed, they will have the figures of the U. S. Bureau of Fisheries for depth, temperature, and salinity to go with them. I am not in a position to say when this study will be finished."

Professor Gayle Scott of Texas Christian University states that he is completing a paper which is tentatively entitled "Paleoecological factors suggested by the pyrite faunas of the Washita and Eagle Ford Cretaceous groups in Texas." An abstract of this paper was published in the Bulletin of the Geological Society of America, vol. 51, p. 1977, 1940.

Mr. Frank Lozo, Professor Scott reports, has a paper on the "Biostratigraphy of the Trinity and Fredericksburg Foraminifera" practically ready for press.

WESTERN UNITED STATES

Mr. Wyatt Durham, a graduate student of Professor Bruce L. Clark of the University of California, is now engaged in a study of the depth and temperature ranges of corals and mollusks. After more than a year's work Mr. Durham has covered about half of the existing literature, and it is hoped that the remainder can be covered during the coming year. Mr. Durham expects to be able to give both depth and temperature ranges for the genera that are being studied. While a member of the Scripps Institution expedition to the Gulf of California he obtained important data from dredgings. An abstract covering preliminary results of Mr. Durham's work is as follows:

"The survey was made to determine whether or not the living gastropod genera are restricted in their bathymetric distribution. Data pertaining to each species was obtained from works on recent mollusca and assembled on cards, including the locality, depth, temperature, type of bottom, number of specimens and mode of occurrence. Where depth has not been reported the occurrence has not been used; unfortunately, this eliminates a majority of the reports. Assistance in the compilation of the data was furnished by the personnel of the Works Project Administration, Official Project No. 65-1-08-62, Unit A-1. Approximately 9000 records have been assembled to date. For preliminary analysis the localities have been referred to three climatic zones on the basis of surface temperature. Cards for a given genus were then assembled as to zone and the maximum, minimum, and median depth ranges determined.

"Significant results are: Some genera are stenobathic, as Thais (climatic range 5 to 20 degrees C., 59 records), depth 0 to 129 meters, median 19 meters; other genera are eurybathic, as Fusus (climatic range above 20 degrees C., 66 records), depth 0 to 1849 meters, median 183 meters; third, the most closely restricted taxonomic units have the most restricted range, as Bursa (sensu lato) (28 records), depth 0 to 289 meters, median 27 meters, while Bursa (Colubrinella) (14 records) ranges from 0 to 27 meters with a median of approximately 0 meters.

"It is hoped that future reports on recent mollusca will include depth, temperature, type of bottom, number and condition of specimens. Information as to sources of additional data will be greatly appreciated."

Dean E. L. Packard of Oregon State College, reports that an Institute of Marine Biology has recently been organized and located at Coos Bay. Some of the students are starting problems in marine ecology.

Professor Hubert G. Schenck of Stanford University states that he and Miss A. Myra Keen have continued their work on the use of mollusks in statistical studies of distribution. They have read proof on an article on "Biometrical analysis of molluscan assemblages" designed for publication in France, but owing to the war it appears doubtful if it will be published. They are, therefore, preparing a somewhat modified and enlarged treatment of the same general subject to be published in this country.

Professor Schenck is endeavoring to organize at Stanford University a course in biostratigraphy for undergraduate students.

Miss A. Myra Keen is making a study of the ecology of living mollusks on the West Coast and will be carrying on field work in the Gulf of California this year. She is continuing her observations in the vicinity of Half Moon Bay.

Mr. W. Thomas Rothwell, Jr., is conducting an ecologic study of Recent barnacles so as to suggest possible conditions of life for closely related fossil forms. An abstract of a part of this work was published in Bulletin of Geological Society of America, vol. 51, p. 1987, 1940.

Dr. W. P. Woodring of the U. S. Geological Survey in a letter dated March 6, 1941, refers to two geological reports containing paleoecological information that are now in press. He states:

"Under the heading 'Environment suggested by fossils' Ralph Stewart and I discuss in a report that will presumably be issued in a month or two the paleoecological implications of a succession of Pliocene invertebrate faunas, mostly mollusks, that lived in a California inland sea (W.P. Woodring, Ralph Stewart, and R. W. Richards: Geology of the Kettlemen Hills oil field, California; stratigraphy, paleontology, and structure: U. S. Geol. Survey Prof. Paper 195). Under the same heading I discuss the paleontological interpretations of Pleistocene molluscan faunas from the San Pedro, California, district. The report containing this discussion is in the hands of the Editor of the Geological Survey, but it is expected that it will not be issued for several years (W. P. Woodring, M. N. Bramlette, and W. S. W. Kew, Geology and paleontology of the Palos Verdes Hills, California)."

OUTSIDE THE UNITED STATES

Professor C. H. Edmondson who is in charge of the Marine Laboratory at Waikiki Beach in Hawaii has the following papers in press and in preparation:

Viability of the coconut seed after floating in the sea. In press, B. P. Bishop Museum. An account of experiments determining that coconuts will sprout after floating in sea water for at least 110 days.

The shipworms of Hawaii. Manuscript will be ready for the press about May 1st, 1941. A taxonomic survey of the waters about Oahu from 14 stations. Four or five new species are described, with observations on the early stages of some. A new internal parasitic copepod is announced, infesting at least three species of local shipworms.

The preceding paper will be followed by one covering the shipworms of the Hawaiian Archipelago, and that one by a survey of these animals of the entire central Pacific, if the material can be obtained.

The Callianassidae of Hawaii. Work on the mud shrimps has been in progress for some time and will probably be brought to conclusion some time this year.

H. S. Ladd and J. E. Hoffmeister have recently completed and sent to press a comprehensive report of the geology of Lau (eastern Fiji). In this study special attention was paid to the thick sections of fossiliferous limestones that are found on many of the islands. Some of these rocks represent elevated coral reefs, others apparently are beds that accumulated below the depth limit of reef-building corals, under a variety of ecological conditions. The organic make-up and petrography of the limestones was studied by G. W. Crickmay, and a series of chemical analyses was made by J. W. Sanders, Jr. The origin and history of the existing reefs of Lau are also discussed.

Hoffmeister and Ladd are preparing a third paper of a series dealing with the general problem of coral reef origin. This one is devoted primarily to an exposition of the Antecedent Platform Theory of reef origin and is based in large part on the authors' work in Fiji and Tonga.

Dr. Earl H. Myers has studied the life history and ecology of many species of Foraminifera in southern England, the Mediterranian Sea, and the East Indies while working under fellowships from the Guggenheim Foundation and the Treub Laboratories of the Netherlands East Indies. He contributes an article to this report.

Dr. Horace G. Richards, in reporting on work done outside the United States, writes:

"In 1939 I collected Miocene and Pleistocene fossils from Margarita Island, Venezuela. While the reports on these fossils largely consist of lists and notes on geographical and geological distribution, brief attention was paid to the ecological conditions indicated by the fossils.

"Collections of recent mollusks made on Cozumel Island (Mexico), Roatan Island (Honduras), Corn Island (Nicaragua), and Margarita Island (Venezuela), were used to attempt to work out the paleogeography of certain areas in the Caribbean."

SOME RECENTLY PUBLISHED PAPERS

Most of the papers listed below have been published very recently. Though by no means complete the lists may give some idea of the variety of ecological and paleoecological investigations that have recently been completed.

PALEOECOLOGY

Bradley, W. H., and others, Geology and biology of North Atlantic deep-sea cores, Pts. 1 and 2, U. S. Geol. Survey Prof. Paper 196-A, pp. i-xv, 1-56, 1940. This paper includes the first parts of an exhaustive study of 11 deep-sea cores taken in the Atlantic Ocean between the Newfoundland banks and the banks off the Irish coast. Some idea of the completeness of the study may be obtained from the outline given below.

Foreword, by C. S. Piggot.
General Introduction, by W. H. Bradley.
Part 1. Lithology and geologic interpretations, by M. N. Bramlette and W. H. Bradley.
2. Foraminifera, by Joseph A. Cushman and Lloyd G. Henbest.
3. Diatomaceae, by Kenneth E. Lohman.
4. Ostracoda, by Willis L. Tressler.
5. Mollusca, by Harold A. Rehder.
6. Echinodermata, by Austin H. Clark.
7. Miscellaneous fossils and significance of faunal distribution, by Lloyd G. Henbest.
8. Organic matter content, by Parker D. Trask, H. Whitman Patnode, Jesse LeRoy Stimson, and John R. Gay.
9. Selenium content and chemical analyses, by Glen Edgington and H. G. Byers.

The parts already issued are prefaced by an excellent summary of the complete report. The remaining parts of this highly significant study will be awaited with much interest.

Bruff, Stephen C., Pleistocene history of the Newport Bay area, southern California, (abstract) Bull. Geol. Soc. Amer., vol. 51, p. 1981, 1940.

Earland, Arthur, Chalk: its riddles and some possible solutions, Trans. Herfordshire Nat. Hist. Soc., vol. 21, pt. 1, pp. 6-37, 1939.

Eaton, J. Edmund, Tie-ins between the marine and continental records in California, Amer. Jour. Sci., vol. 237, pp. 899-919, 1939.

Vokes, H. E., Paleoecology of the fauna of the Domengine formation, middle Eocene, California, Proc. Sixth Pacific Sci. Cong., pp. 597-605, 1939.

PLANTS

Fenton, Carroll Lane, and Fenton, Mildred Adams, Pre-Cambrian and Paleozoic algae, Bull. Geol. Soc. Amer., vol. 50, pp. 89-126, 1939.

Form-genera and form-species of algae are shown to persist over considerable areas in spite of variation in the sediments containing them. Some of the form-species produced massive biostromes, others "mottled" the dolomites or produced irregular layers. Fluctuations within form-species may be correlated with evidence for environmental variation.

Johnson, J. Harlan, Lime-secreting algae and algal limestones from the Pennsylvanian of central Colorado, Bull. Geol. Soc. America, vol. 51, pp. 571-596, 1940.

Fourteen species, ten of which are new, are described on the basis of form genera and form species. Each form species may have represented several biologic species which lived in constant close association. These species, it is thought, formed a colony under a definite set of ecological conditions. This assemblage changed with the changing environment, producing differences in the shape or character of the colony. Similar developments are known among modern groups. Growth forms, lithology and sedimentary structures are used to support generalizations regarding environment.

Moldenke, Harold N., Marine flowering plants, Torreya, vol. 40, pp. 120-124, 1940.

According to Dr. Roland W. Brown, this article lists the more common marine flowering plants with comments on geographic distribution and habitat.

FORAMINIFERA

Crickmay, G. W., Ladd, H. S., and Hoffmeister, J. E., Shallow-water Globigerina sediments, Bull. Geol. Soc. Amer., vol. 52, pp. 79-106, 1941.

Highly calcareous Neogene sediments rich in Globigerinidae are described from three islands in eastern Fiji; comparisons are

made with other types of Globigerina sediments both ancient and modern from various parts of the world.

Cushman, Joseph A., A study of the Foraminifera contained in cores from the Bartlett Deep, Amer. Jour. Sci., vol. 239, pp. 128-147, 1941.

Material is described from three cores collected south of Cuba in water exceeding 2,500 fathoms. Content of Foraminifera in cores varies considerably, indicating a periodic absence of pelagic forms. This condition may possibly be due to changes in position of warm currents during ice periods.

Earland, Arthur, Some notes on selective building, Trans. Hertfordshire Nat. Hist. Soc., vol. 21, pp. 106-114, 1939.

Henbest, L. G., Lohman, K. E., and Mansfield, W. C., Foraminifera, diatoms, and mollusks from test wells near Elizabeth City, N.C., U. S. Geol. Surv., Prof. Paper 189-G, 1939.

Myers, Earl H., Observations on the origin and fate of flagellated gametes in multiple tests of Discorbis (Foraminifera), Jour. Marine Biol. Assoc. of the United Kingdom, vol. 24, pp. 201-226, 1940.

Phleger, Fred B., Jr., Foraminifera of submarine cores from the Continental Slope, Bull. Geol. Soc. Amer., vol. 50, pp. 1395-1422, 1939.

_____, Collecting pelagic Foraminifera, Science, vol. 92, pp. 553-554, 1940.

_____, Foraminifera of submarine cores from North Atlantic, Bull. Geol. Soc. Amer., vol. 51, p. 1975, 1940.

Vaughan, T. Wayland, and Cole, W. Storrs, Preliminary report on the Cretaceous and Tertiary larger Foraminifera of Trinidad, British West Indies, Geol. Soc. Amer., Spl. Papers, No. 30, pp. 1-137, 1941.

ECHINOIDS

Schoonover, Lois M., A Miocene echinoid colony from Maryland, Jour. Paleo., vol. 15, pp. 92-93, 1941.

MOLLUSKS AND ASSOCIATED ORGANISMS

Andrews, E. A., The snail, Neritina virginea L., in a changing salt pond, Ecology, vol. 21, pp. 335-346, 1940.

_____, Neritina virginea L., in Jamaica, B. W. I., Nautilus, vol. 54, pp. 21-27; 66-68; 98-106, 1940-41.

The above two papers are parts of an interesting study which shows that in Jamaica the species is smaller and its shell less pigmented in saline environments. These differences and others may not follow life in saline environment but may be due, in part at least, to other factors, such as insolation. Additional experimental work is to be carried on.

Broekhuysen, G. J., A preliminary investigation of the importance of desiccation, temperature and salinity as factors controlling the vertical distribution of certain intertidal marine gastropods in False Bay, South Africa (Papers on the Ecology of the South African Coast, from the Zoological Dept., Univ. of Cape Town, No. 12. Reference to earlier numbers of this series of papers is given by Vaughan in his Presidential Address, previously referred to), Trans. Royal Soc. South Africa, vol. 28, pt. III, 1940.

Flower, Rousseau H., Study of the Pseudorthoceratidae, Pal. Americana, vol. 2, No. 10, pp. 1-214, 1939.

Includes several pages (66-75) on "Mode of life and ecological significance of siphonal and cameral deposits."

Gunter, Gordon, Comments on the shape, growth, and quality of the American oyster, Science, vol. 88, pp. 546-547, 1938.

Haas, Fritz, Ecological observations on the common molluscs of Sanibel Island, Florida, Amer. Midland Naturalist, vol. 24, pp. 369-378, 1940.

A brief but interesting account of the common forms of the beach under ordinary conditions and a description of the changes that follow storms; also includes brief descriptions of environments on landward side of island.

Hewatt, Willis G., Observations on the homing Limpet, Acmaea scabra Gould, Amer. Midland Naturalist, vol. 24, pp. 205-208, 1940.

MacGinitie, G. E., Littoral marine communities, Amer. Midland Naturalist, vol. 21, pp. 28-55, 1939.

Paleontologists will find much of interest in this paper. First of all it gives brief evaluations of the more outstanding works on the fauna of marine communities. It points out that marine animal communities are not static and shows further that no apparatus has yet been devised to give a complete picture of ocean bottom communities. It offers a simple and convenient classification of benthal habitats. Stress is laid on a knowledge of the life histories of individual species. When these are known, the ecologist will be better able to recognize occurrences outside the natural habitats.

Milne, A., Some ecological aspects of the intertidal area of the estuary of the Aberdeenshire Dee, Trans. Royal Soc. Edinburgh, vol. 60, pt. 1, pp. 107-139, 1940 (Biol. Absts. vol. 14, p. 1106, 1940).

Nomura, S., On the molluscan fauna dredged from Matusima Bay during Feb. 10-13, 1937, by Dr. S. Yoshemuai, Saito Hō-on Kai Mus., Research Bull. No. 19, pp. 1-12, 1940.

Includes a list of species from 46 stations; gives depth, bottom temperature, and nature of bottom.

Pearse, A. S., Estuarine animals at Beaufort, North Carolina, Jour. Elisha Mitchell Sci. Soc., vol. 52, pp. 174-222, 1936.

Studies such as this one are of particular interest to paleoecologists. Collections were made at 22 stations extending from open ocean to fresh water streams and ponds lying 20 miles from the coast at points where salt water never enters; includes determinations of salinity, oxygen, pH, and temperature.

Perry, Louise M., Marine shells of the southwest coast of Florida, Bull. Amer. Paleo., vol. 26, No. 95, pp. 1-266, 1940.

Includes notes on habitats of some mollusks.

Richards, Horace G., Marine Pleistocene of the Gulf Coastal Plain: Alabama, Mississippi, Louisiana, Bull. Geol. Soc. Amer., vol. 50, pp. 297-316, 1939.

_____, Marine Pleistocene of Texas, Bull. Geol. Soc. Amer., vol. 50, pp. 1885-1898, 1939.

_____, Marine Pleistocene Fossils from Newfoundland, Bull. Geol. Soc. Amer., vol. 51, pp. 1781-1788, 1940.

Richards, Horace G., Moluscos coleccionados en la Isla de Margarita, Boletin de la Sociedad Venezolana de Ciencias Naturales, No. 46, Tomo 6, 302-307, 1940.

Scott, Gayle, Paleoecological factors controlling the distribution and mode of life of Cretaceous Ammonoids in the Texas Area, Jour. Paleo., vol. 14, pp. 299-323, 1940; also published Bull. Amer. Assoc. Petr.Geol., vol. 24, pp. 1164-1203, 1940.

This excellent address is a major contribution to paleoecology and deserves the wide distribution given it by simultaneous publication in two journals. Having thus been made readily available to most geologists further comment here seems unnecessary.

Spooner, G. M., and Moore, H. B., The ecology of the Tamar Estuary, VI, an account of the macrofauna of the intertidal muds, Jour. Mar. Biol. Assoc. of United Kingdom, vol. 24, pp. 283-330, 1940.

Villee, C. A., and Groody, T. C., The behavior of limpets with reference to their homing instinct, Amer. Midland Naturalist, vol. 24, pp. 190-204, 1940.

ARTHROPODS

Tressler, Willis L., Ostracoda from Beaufort, N.C., sand beaches, Amer. Midland Naturalist, vol. 24, pp. 365-368, 1940.

VERTEBRATES

Davidson, Frederick A., and Hutchinson, Samuel J., The geographic distribution and environmental limitations of the Pacific salmon (Genus Oncorhynchus), Bur. Fisheries, vol. 48, Bull. 26, pp. 667-692, 1938.

MISCELLANEOUS REPORTS

Dr. Remington Kellogg has suggested that the Discovery and Norwegian reports listed below be included. He points out that they cover a wide variety of subject and contain a great deal of the finest ecological work that has been done in recent years, yet apparently they are not widely known among geologists in this country.

Discovery Reports, Cambridge Univ. Press.

Vol. 2, pp. 1-22. Polychaete worms, by C.C.A. Monro. 1930.
Vol. 2, pp. 223-260, pl. 1. Thoracic cirripedes. Collected in 1925-1927, by C. A. Nilsson-Cantell. 1930.
Vol. 2, pp. 261-370, pl. 2. Oceanic fishes and flatfishes. Collected in 1925-1927, by J. R. Norman. 1930.

Vol. 2, pp. 371-402, pls. 3-4. I. Octopoda, by G. C. Robson. 1930.
Vol. 3, pp. 199-222. Nebaliacea, by H. Graham Cannon. 1931.
Vol. 3, pp. 267-296, pl. 39. Mollusca: Gastropoda Thecosomata and Gymnosomata, by Anne L. Lassy. 1932.
Vol. 4, pp. 291-460, pls. 6-17. Foraminifera Pt. 1. The ice-free area of the Falkland Islands and adjacent seas, by E. Heron-Allen and A. Earland. 1932.
Vol. 5, pp. 1-326, pl. 1. Amphipoda, by K. H. Barnard. 1932.
Vol. 5, pp. 467-484, pl. 4. Lobster-krill; Anomuran Crustacea that are the food of whales, by L. Harrison Matthews. 1932.
Vol. 6, pp. 1-138. Pycnogonida, by Isabella Gordon. 1932.
Vol. 6, pp. 165-190, pls. 7-42. On the distribution and movements of whales on the South Georgia and South Shetland whaling grounds, by Stanley Kemp and A. G. Bennett. 1932.
Vol. 6, pp. 237-392, pls. 48-57. Sponges, by M. Burton. 1932.
Vol. 7, pp. 1-16. Fossil Foraminifera from the Burdwood Bank and their geological significance, by W. A. MacFadyen. 1933.
Vol. 7, pp. 27-138, pls. 1-7. Foraminifera, Part 2, by Arthur Earland. 1933.
Vol. 7, pp. 171-238, pls. 8-10. A general account of the hydrology of the South Atlantic Ocean, by G. E. R. Deacon. 1933.
Vol. 7, pp. 253-362, pl. 14. Isopod Crustacea, Part 1. The family Serolidae, by Edith M. Sheppard. 1933.
Vol. 8, pp. 1-268. On the Phytoplankton of the South-West Atlantic and the Bellingshausen Sea, 1929-31, by T. J. Hart. 1934.
Vol. 8, pp. 329-396, pls. 14-15. Scyphomedusae, by G. Stiasny. 1934.
Vol. 9, pp. 1-64. Hydrology of the Bransfield Strait, by A. J. Clowes. 1934.
Vol. 9, pp. 65-160. Distribution of the Macroplankton in the Atlantic Sector of the Antarctic, by N. A. Mackintosh. 1934.
Vol. 9, pp. 175-206, pls. 2-14. The marine deposits of the Patagonian Continental shelf, by L. Harrison Matthews. 1934.
Vol. 9, pp. 215-294, pls. 15-16. Nemerteans from the South Atlantic and Southern Oceans, by J. F. G. Wheeler. 1934.
Vol. 9, pp. 295-350, pls. 17-22. The sea-floor deposits: I. General characters and distribution, by E. Neaverson. 1934.
Vol. 10, pp. 1-208, pls. 10. Foraminifera, Part III. The Falklands Sector of the Antarctic (excluding South Georgia), by Arthur Earland. 1934.
Vol. 10, pp. 209-246. The Falkland species of the crustacean genus Munida, by G. W. Rayner. 1935.
Vol. 11, pp. 1-456. The plankton of the South Georgia whaling grounds and adjacent waters, 1926-1927, by A. C. Hardy and E. R. Gunther. 1935.
Vol. 11, pp. 457-510, pls. 5. The continuous plankton recorder, by A. C. Hardy, with an appendix: A test of the validity of the continuous plankton recorder method, by A. C. Hardy and Nora Ennis. 1936.

Vol. 11, pp. 511-538. Observations on the uneven distribution of oceanic plankton, by A. C. Hardy. 1936.
Vol. 12, pp. 1-58. Coast fishes. Part 1. The South Atlantic, by J. R. Norman. 1935.
Vol. 12, pp. 59-198. Polychaete worms, II, by C. C. A. Monro. 1936.
Vol. 12, pp. 199-348, pls. 9. Echinoidea and Ophiuroidea, by Th. Mortensen. 1936.
Vol. 12, pp. 377-440. Larvae of Decapod Crustacea. Part 1. Stenopidea, Part 2. Amphionidae, Part 3. Phyllosoma, by Robert Gurney. 1936.
Vol. 13, pp. 1-76, pls. 1-2. Foraminifera. Part 4. Additional records from the Weddell Sea sector from material obtained by the S. Y. 'Scotia', by Arthur Earland. 1936.
Vol. 13, pp. 107-276, pls. 14-16. A report on oceanographical investigations in the Peru coastal current, by E. R. Gunther. 1936.
Vol. 14, pp. 1-192. On the development and distribution of the young stages of krill (Euphausia superba), by F. C. Fraser. 1936.
Vol. 14, pp. 193-324. The southern species of the genus Euphausia, by D. Dilwyn John. 1936.
Vol. 15, pp. 1-124. The hydrology of the Southern Ocean, by G. E. R. Deacon. 1937.
Vol. 15, pp. 125-152. Note on the dynamics of the Southern Ocean, by G. E. R. Deacon. 1937.
Vol. 15, pp. 153-222. New species of marine mollusca from New Zealand, by A. W. B. Powell. 1937.
Vol. 16, pp. 1-150. Coast Fishes. II. The Patagonian region, by J. R. Norman. 1937.
Vol. 16, pp. 151-364. The plankton diatoms of the southern seas, by N. Ingram Hendey. 1937. (See comment by Lohman in present report.)
Vol. 16, pp. 365-412. The seasonal circulation of the Antarctic macroplankton, by N. A. Mackintosh. 1937.
Vol. 16, pp. 413-446. Rhizosolenia curvata Zacharias, an indicator species in the Southern Ocean, by T. John Hart. 1937.
Vol. 18, pp. 1-105. Coast Fishes. III. The Antarctic zone, by J. R. Norman. 1938.
Vol. 18, pp. 121-222. Crinoidea, by D. Dilwyn John. 1938.
Vol. 18, pp. 223-238. Thoracic cirripedes collected in 1935-1936, by C. A. Nilsson-Cantell. 1939.
Vol. 18, pp. 239-264. The leopard seal Hydrurga leptonyx (De Blainville), by J. E. Hamilton. 1939.
Vol. 18, pp. 265-322. Hydromedusae from the Falkland Islands, by (the late) Edward T. Browne and P. L. Kramp. 1939.
Vol. 18, pp. 323-338. Madreporarian corals, with an account of variation in Caryophyllia, by J. Stanley Gardiner. 1939.
Vol. 20, pp. 1-68. Larvae of decapod crustacea. IV. The genus Sergestes, by R. Gurney and M. V. Lebour. 1940.
Vol. 20, pp. 69-306. Asteroidea, by Walter K. Fisher. 1940.

Hvalrådets Skrifter, Scientific Results of Marine Biological Research, Det Norske Videnskaps-Akademi i Oslo.

No. 1, pp. 1-88, figs. 21. Hydrographical and chemical investigations in the coastal waters off Møre and in the Romsdalsfjord, by Trygve Braarud and Alf Klem. 1931.

No. 2, pp. 1-105, figs. 37. On the biology of southern Euphausiidae, by Johan T. Ruud. 1932.

No. 3, pp. 1-37, charts 6. Norwegian pelagic whaling in the Antarctic. I. Whaling grounds in 1929-1930, and 1930-1931, by Johan Hjort, J. Lie, and Johan T. Ruud. 1932.

No. 4, pp. 1-44, figs. 19. The "Øst" expedition to the Denmark Strait 1929, I. Hydrography, by Trygve Braarud and Johan T. Ruud. 1932.

No. 5, pp. 1-61, figs. 8. On the biology of some southern Copepoda, by Per Ottestad. 1932.

No. 7, pp. 1-152, pls. 6. Essays on population. 1933.

No. 8, pp. 1-36, pls. 2. Norwegian pelagic whaling in the Antarctic, by Johan Hjort, J. Lie, and Johan T. Ruud. III. The season 1932-1933. 1933.

No. 9, pp. 1-59, pls. 7. Pelagic whaling in the Antarctic. IV. The season 1933-1934, by Johan Hjort, J. Lie, and Johan T. Ruud. 1934.

No. 10, pp. 1-173, figs. 38. The "Øst" expedition to the Denmark Strait 1929. II. The phytoplankton and its conditions of growth (including some qualitative data from the Arctic in 1930), by Trygve Braarud. 1935.

No. 12, pp. 1-52, Pelagic whaling in the Antarctic. V. The season 1934-1935, by Johan Hjort, J. Lie, and Johan T. Ruud. 1935.

No. 14, pp. 1-45, pls. 2. Pelagic whaling in the Antarctic. VI. The season 1935-1936, by Johan Hjort, J. Lie, and Johan T. Ruud. 1937.

No. 15, pp. 1-56, figs. 24. The hydrographic conditions and aeration of the Oslo Fjord 1933-1934, by Trygve Braarud, and Johan T. Ruud. 1937.

No. 17, pp. 1-151, pl. Deep-sea prawn fisheries and their problems, by Johan Hjort and Johan T. Ruud. 1938.

No. 18, pp. 1-68, figs. 15, pls. 2. Pelagic whaling in the Antarctic. VII. The season 1936-1937, by Johan Hjort, J. Lie, and Johan T. Ruud. 1938.

No. 19, pp. 1-63, figs. 9. The phytoplankton of the Oslo Fjord 1933-1934, by Trygve Braarud and Adam Bursa. 1939.

No. 20, pp. 1-42, pls. 2, figs. 6. Pelagic whaling in the Antarctic. VIII. The season 1937-1938, by Birger Bergersen, J. Lie, and Johan T. Ruud. 1939.

No. 21, pp. 1-85, figs. 5, tables 2. The production of zooplankton in the Oslo Fjord in 1922-1923, by Kristian Fredrik Wiborg. 1940.

At the suggestion of Mr. H. C. Stetson, special mention is also made at this point of the classical studies of C. G. J. Petersen of the bottom populations in the shallow sounds of the Baltic.

Animal life of the sea bottom, its food and quantity, Reports of the Danish Biological Station, vol. 20, 1911.

Animal communities of the sea bottom and their importance for marine zoogeography, Reports of the Danish Biological Station, vol. 21, 1913.

Though these reports contain much information of value to stratigraphers and paleontologists it is doubtful if most geologists are familiar with them.

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Addendum.- After the manuscript of this report had been completed the following paper was received:

Stephenson, T. A., A summary account of the ecological survey of the South African coast carried out from the University of Cape Town during the years 1931-40, pp. 14, March 1941. Privately published.

This paper contains a brief summary of the results obtained from the survey and a list of all publications on it, including a few not yet printed. This is the most important investigation of its kind that has yet been done.

ECOLOGY OF DIATOMS

by

Kenneth E. Lohman

Ecologic studies of various degrees of completeness have claimed at least partial attention of nearly every student of diatoms for the last hundred years or more. To attempt a complete review of the literature of diatom ecology thus becomes a task whose magnitude is out of all proportion to the needs of the present report. It appears more practicable, therefore, to give an annotated bibliography of some of the papers that contain definite ecologic data with full awareness that the list is only fragmentary, and that many papers of at least equal merit have been omitted. The papers included represent the type and scope of the work done to date on diatom ecology, rather than its total quantity.

Although this committee is primarily concerned with the ecology of marine organisms, diatoms occur in a much wider range of environments than this title indicates. This report, therefore, has been expanded to include papers dealing with fresh-water, brackish-water, and saline lake diatoms as well as with those living under marine conditions. Several papers in the field of paleoecology have been included for a number of reasons among which are the following:

One of the useful results of studies of the ecology of living organisms is the means thus given of making some kind of approximation regarding the environmental conditions under which fossils were deposited and thereby obtain geologic data of considerable value in the interpretation of associated sediments. It is true that this extrapolation from the known environments of today to those of previous periods of earth history is based, in part at least, on the assumption that the organism has always lived in the same type of environment. Disregarding for the moment the philosophical arguments against such an assumption, studies of many fossil diatom floras give satisfactory indications that the assumption is a reasonably sound one, and that interpretations based on it are as accurate as can be obtained with the data available. For this reason accurate determination of the species living in a wide range of environments is a fundamental requirement for subsequent work of this kind.

In spite of the large volume of approximate and qualitative ecologic data available to students of diatoms, a real need exists for more specific and quantitative information, such as has been supplied by some of the recent oceanographic expeditions.

RECENT MARINE

Castracane, degli Antelminelli, Conte Abbe Francesco, Report on the Diatomaceae collected by H.M.S. Challenger during the years 1873-1876: Challenger Repts., Botany, vol. 2, pp. 1-178, pl. 1-30, 1886.

One of the early oceanographic expeditions and containing a short account of the biology of diatoms, their bathymetrical limit, and an hypothesis on the formation of banks and deposits of diatoms. The bulk of the paper deals with systematic descriptions of species (a very large number of which are listed as new) with minimum ecologic and geographic data.

Karsten, George, Die Diatomeen der Kieler Bucht: Wissenschaftliche Meersuntersuchungen herausgegeben von der Kommission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel, neue Folge, Band 4, pp. 17-205, figs. 1-219, 1899.

A little known paper with excellent ecologic information regarding the variations in the diatom flora in the Bay of Kiel with a detailed discussion of the factors believed responsible. The systematic treatment is poor, illustrations better than fair with a thorough description of the cell contents, chromatophores and resting spores.

Gran, H. H., Diatomaceae from the ice-floes and plankton of the Arctic Ocean: The Norwegian North Polar Expedition, 1893-1896, Scientific Results, vol. 4, pp. 1-74, pl. 1-3, 1904.

Probably the best discussion of ice-floe diatoms and considerations of their probable sources.

Mann, Albert, Report on the diatoms of the Albatross Voyages in the Pacific Ocean, 1888-1904: Contr. U. S. Nat. Herbarium, vol. 10, part 5, pp. 221-442, pl. 44-54, 1907.

Good locality data of hydrographic dredging and trawling stations with surface and bottom temperatures, depth of water, and kind of bottom. No formal discussion of ecology, but much information can be obtained by patient search through the locality table and then checking back on the systematic part. The synonymy (by P. L. Ricker) is excellent, but the paper would have been much more usable if a few tables had been inserted correlating the ecologic data.

Heurck, Henri Van, Diatomées. Résultats du Voyage du S. Y. "Belgica" en 1897-1899: Expédition Antarctique Belge, VI, Botany, pp. 1-26, pl. 1-13, 1909.

In addition to good systematic treatment this paper contains some valuable tables giving a comparison of the distribution of diatoms of all expeditions prior to 1909 in both the Arctic and Antarctic Oceans. Ecologic data are in general broad and spotty, with only occasional detailed information.

Heiden, Heinrich, and Kolbe, R. W., Die marinen Diatomeen der deutschen Südpolar-Expedition, 1901-1903.: Deutsche Südpolar-Expedition, Band 8, Botanik, Heft 5, pp. 450-714, pl. 31-43, 1928.

A large amount of ecologic information, particularly regarding temperatures of a great many stations in the Antarctic Ocean, together with good systematic treatment.

Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs und der Schweiz: Rabenhorst's Kryptogamen-Flora Deutschlands, Österreichs und der Schweiz, Band 7, Teil 1, pp. 1-919, 542 figs., 1927-1930; Teil 2, pp. 1-576, figs. 543-1008, 1931-1933 (incomplete).

Unfortunately this remarkable work is unfinished, and it is to be hoped that it will be finished when the war is over, as it is probably the most outstanding work on living diatoms ever published. The systematic descriptions are very complete and contain much quantitative data. The ecologic data, although frequently lacking in quantitative information, are amazingly complete considering the amount of ground covered.

Thorp, Eldon Marion, Calcareous shallow-water marine deposits of Florida and the Bahamas: Carnegie Inst. Wash. Publ. No. 452, pp. 37-143, 5 pls. and 14 text figs., 1935. Three appendices accompany this paper:

1. Diatoms in bottom deposits from the Bahamas and the Florida Keys, by Albert Mann.
2. Current measurements along the Florida coral reef tract, by T. W. Vaughan.
3. Notes on current observations, Florida Keys, June, October, November, 1914, by Frank J. Haight.

Many mechanical analyses of the sediments, lists of organisms found, several ecologic factors such as temperature, nutrient material, oolites, minerals, chemical properties are evaluated. Although the discussion of the diatoms is very brief, some ecologic data regarding them can be obtained by referring to stations at which they were found in the main body of the paper.

Hendey, N. Ingram, The plankton diatoms of the Southern Seas: Discovery Reports, vol. 16, pp. 151-364, pl. 6-13, 1937.

An excellent paper giving the diatoms found, their relative abundance, depth of catch, water temperature, salinity, pH, phosphate content, combined nitrite and nitrate content, and locations of 206 collections made on expeditions of the R. R. S. Discovery, R. R. S. Discovery II, R. R. S. William Scoresby, and S. S. C. A. Larsen. Some collections were also made by the Marine Biological Station in East Cumberland Bay, South Georgia. Outside limits for the collections were between 10° North and 70° South latitude and between 50° East and 100° West longitude. The larger part came from between 50° and 65° South latitude and between 10° and 70° West longitude.

Besides the unusually complete ecologic data presented (probably the most complete of any) the paper contains a revision of Schütt's classification of the diatoms, descriptions of all species found, illustrations of some and a limited synonymy.

RECENT NON-MARINE

Schumann, Julius, Die Diatomeen der hohen Tatra: Verh. Zool. bot Gesell. Wien, Suppl., Band 17, pp. 1-102, pl. 1-4, 1867.

An early study of the relation of fineness of striation of fresh-water diatoms to the temperature of the water and the altitude at which they live. His conclusions were that temperature was the most important factor, although altitude was sufficiently important to enable him to determine elevations by counting the striae on diatoms.

Héribaud, Joseph, De l'influence de la lumière et de l'altitude sur la striation des valves des diatomées: Comptes-rendus Acad. Sci. Paris, Tome 118, pp. 82-84, 1894.

Héribaud confirmed Schumann's claims in studies of the diatoms from the Lakes of Auvergne. His conclusions are:

1. Under the influence of a feeble illumination, probably approaching the physical darkness which exists at 13 to 15 meters in the Lakes of Auvergne, the striation of the valves of diatoms is less compact; and the general form of the frustules is more elongated and narrow.
2. The striae are more numerous and less robust at higher altitudes.

Hustedt, Friedrich, Bacillariophyta (Diatomeae): Pascher, A., Die Susswasser-Flora Mitteleuropas, Heft 10, 2nd ed., pp. 1-466, 875 figs., 1930.

An indispensible work on non-marine diatoms with excellent descriptions, figures, and very complete (if somewhat lacking in quantitative data) ecologic information on the fresh-water diatoms of central Europe.

Cleve-Euler, Astrid, Die Kieselalgen des Tåkernsees in Schweden: Kungl. svenska vetensk. Akad. Handl., 3d ser., Band 11, No. 2, pp. 1-254, 378 figs., 1932.

587 species of fresh-water diatoms are briefly described, discussed, and over 300 are illustrated in the first half of the paper. The second half contains a very complete and well organized discussion of the ecology of a large number of diatom floras from Swedish lakes.

Kindle, E. M., The role of thermal stratification in lacustrine sedimentation: Royal Soc. Canada Trans., ser. 3, vol. 21, pp. 1-35, 6 text figs., pl. 1-3, 1927.

The lists of diatoms in this paper occupy a somewhat subordinate position, but the ecologic factors indicated by the title are well presented and correlated with the diatom floras.

Hanna, G. D., and Grant, W. M., Diatoms of Pyramid Lake, Nevada: Trans. Am. Microscopical Soc., vol. 50, No. 4, pp. 281-297, pls. 25-27, 1931.

The salinity of Pyramid Lake is about one-tenth that of sea water with a somewhat higher percentage of carbonates. The diatom flora obtained contains some marine and brackish forms as well as some characteristic of saline lakes elsewhere. 13 species are discussed and figured, and the synonymy is ample.

Sovereign, H. E., Unpublished work.

Mr. Sovereign is at present working on a valuable study of the diatom ecology of numerous lakes in the State of Washington. He has made many collections of diatoms, measurements of pH, temperature, salinity, and elevation for each collection and is attempting to evaluate each factor insofar as it affects the growth of diatoms. When last heard from (1939) his results indicated that diatoms could be grouped according to the pH of the water in which they lived, and that this factor was more important than temperature. When finished, his results should be of great value to all students of non-marine diatoms.

PALEOECOLOGY

Lauby, Antoine, Récherches paleophytologiques dans le Massif Central: Services de la Carte géologique de la France, Bulletin no. 125, tome 20, pp. 1-398, pls. 1-14, 1910.

One of the least known and most valuable papers on the stratigraphic ranges and paleoecology of the non-marine diatoms. Lists of species from non-marine sediments in a great many localities in the central plateau of France from Pliocene to Oligocene in age are given together with associated higher plants. The stratigraphy of each locality is discussed, section given, and a separate chapter is included giving ecologic interpretations from the diatom floras.

Hanna, G. Dallas, Diatoms of the Florida peat deposits: Florida State Geol. Survey, 23-24th Ann. Rept., pp. 65-96, pls. 1-11, 1933.

44 samples from peat bogs and swamps in Florida were lumped into two categories: (1) Species which belong to the Peat Bog flora, and (2) Brackish-water species found below the peat deposits. On the evidence offered by the diatoms the author concludes that the peat deposits were formed under the much colder conditions prevailing during one or more glacial stages, and that active deposition of peat is no longer going on. All diatoms found are discussed and well illustrated, and the synonymy is ample.

Lohman, K. E., Diatoms from Quaternarylake beds near Clovis, New Mexico: Jour. Paleontology, vol. 9, No. 5, pp. 455-459, 1935.

A tentative chronologic correlation is made on the basis of a study of 88 species and varieties of diatoms from 13 samples of sand and clay lake deposits. An ecologic census indicates an increase in salinity of the water during deposition going from the bottom to the top of the deposits. An increase in aridity of the region during this interval is suggested as a probable cause.

Patrick, Ruth, Some diatoms of Great Salt Lake: Torrey Bot. Club Bull., vol. 63, pp. 157-166, pl. 6, 1936.

No diatoms are living in Great Salt Lake today, but a series of borings into the deposits underlying the lake yielded fresh-water and brackish-water diatoms, indicating a great increase in the salinity of this lake during Quaternary times.

Hyyppa, Esa, Post-glacial changes of shore-line in South Finland: Commission géologique de Finlande, Bull. no. 120, pp. 1-225, 57 figs., 21 tables, 2 appendices, 1937.

An extremely thorough and objective study in which lithology, pollen, and diatoms are used to trace post-glacial changes in shore lines. The ecologic conditions inferred from the extensive diatom floras obtained at different depths in borings are used to account for the regressions and transgressions of the sea and agree with similar conditions indicated by studies of the lithology and pollen analyses. This paper contains a wealth of information and is probably the most complete and exhaustive study of its kind.

Patrick, Ruth, The occurrence of flints and extinct animals in pluvial deposits near Clovis, New Mexico. Part V, - Diatom evidence from the mammoth pit: Philadelphia Acad. Nat. Sci. Proc., vol. 90, pp. 15-24, 1 text plate, 1938.

An increase in salinity of water during deposition of a series of lake beds containing diatoms, flint artifacts associated with bison and mammoth bones is indicated by a study of the diatoms.

Lohman, K. E., Pliocene diatoms from the Kettleman Hills, California: U. S. Geol. Survey Prof. Paper 189-C, pp. 81-102, pls. 20-23, 1938.

A stratigraphic and ecologic study of three Pliocene formations, Etchegoin, San Joaquin, and Tulare is made on the basis of 232 species and varieties of diatoms. The diatoms indicate that the Etchegoin and San Joaquin formations were deposited under marine conditions which changed to brackish and finally to fresh-water conditions during early Tulare time.

Lohman, K. E., Geology and biology of North Atlantic deep-sea cores. Part 3, Diatomaceae: U. S. Geol. Survey Prof. Paper 196-B, pp. 55-93, pls. 1-2, 11-17, figs. 1, 22, 1941.

An ecologic study of the diatoms in 67 samples from 9 submarine cores taken by C. S. Piggot across the North Atlantic between Newfoundland and England. The presence of a large proportion of neritic, warm-water species in the cores is attributed to slow settling of the diatoms during a northward movement of the water caused by the Gulf Stream and other oceanic currents. 52 species and varieties (of which 3 are described as new) are discussed and illustrated and synonymies given.

RECENT MARINE ECOLOGICAL INVESTIGATIONS OF PALEONTOLOGICAL SIGNIFICANCE AT THE SCRIPPS INSTITUTION OF OCEANOGRAPHY

by

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INTRODUCTION

Marine organisms are of threefold importance in sediments: (1) Remains of their skeletons and tissues make up an appreciable and often a dominant part of the deposits of the sea floor. (2) The physical and chemical conditions within the bottom muds are mainly controlled by organisms, particularly bacteria and those larger, mud-eating forms which like earthworms in garden soil continually churn over and aerate certain types of deposits. (3) The species of organic remains present in a sediment or a sedimentary rock are the chief clues by which it is possible to reconstruct the environment of deposition. From the point of view of the paleontologist and the stratigrapher it is thus not sufficient to study merely the distribution of skeletal remains in Recent sediments laid down under known conditions of temperature and depth. The nature of the biological processes in the overlying water column is also of significance, especially in sediments containing the remains of plankton plants and animals. Likewise important to the geologist in his search for keys to the past is the ecology of bottom-living organisms, even though, like bacteria, they leave no skeletal traces. Since the biochemical processes carried out by bacteria are easily disturbed yet exceedingly slow, they cannot be observed directly. By examination of the vertical distribution of conditions in freshly collected cores, however, it is possible to make a sort of discontinuous motion picture of these processes.

Ecologic investigations along each of the lines suggested above have recently been carried out at the Scripps Institution. Although widely different techniques were used the results all have a common applicability to the problems of interpretation of sedimentary rocks. In order to emphasize the range of problems involved, three recently completed projects and one just begun will be described.

DIATOM PRODUCTION AND DEPOSITION IN THE GULF OF CALIFORNIA

The floor of the Gulf of California is unique, so far as the present sea-bottom is concerned, in that over many thousands of square miles it is covered with a green, finely laminated, highly organic diatomaceous mud which is apparently the modern analogue of the Miocene diatomaceous shales in the California coast ranges. On drying a core of this diatomaceous mud, the laminations are clearly seen as alternating white and green bands about .2 to 1.0 mm. thick, which become more closely spaced as the bottom of the core is approached, probably owing to compaction. Three questions naturally arise in connection with the occurrence of these laminated diatomaceous muds on the Gulf floor: (1) Are the laminations seasonal, perhaps representing seasonal rhythms in the rate of diatom production in the subsurface waters of the Gulf? (2) What peculiar conditions in the water allow the deposition of the diatom frustules on the bottom? (3) What is the origin of the silica continually extracted from the sea water by the diatoms and permanently removed by the deposition of their frustules? It is obvious that these questions can be answered only by an ecological study of diatom production and its control in the Gulf of California.

The seasonal character of phytoplankton production in the Gulf is abundantly demonstrated by observations made on two expeditions to the area on board the E. W. Scripps, one in February and March 1939, and the second from October to December of 1940. On the 1939 cruise, the waters over large areas were reddened and opaque, so great was the phytoplankton population. When the 1940 expedition first reached the Gulf, the surface waters were warm, blue and clear, the phytoplankton population was small and the contents of phosphate and silica, both essential substances for plant growth, were very low. These substances had long since been extracted by plants which had afterwards died or been eaten and had settled out of the surface waters. Interchange of the depleted surface water with nutrient-rich deep water was prevented by the stable density stratification arising from the high temperature of the surface layers. With the development of northwesterly winds of gale force, which began in November, repeated measurements of the vertical distribution of temperature, salinity and oxygen showed that the warm surface water was being blown southward, while upwelling of cold water was taking place. Simultaneous measurements of the amount of dissolved phosphate and silica indicated a marked increase in the surface layers, which was followed by a decrease as growing diatoms and other phytoplankton utilized these substances. That phytoplankton growth was occurring at a relatively rapid rate was shown directly by measuring the amount of photosynthesis taking place in a given column of water between the surface and about 40 meters. This was done by determining the amount of oxygen produced. Amounts of oxygen were liberated in one day equal to about half a gram of dry organic matter per square centimeter of sea surface per year, or about 20 tons of diatoms per acre, per year. At the same time quantitative samples showed a marked increase in phytoplankton population, and small patches of red water were seen in December.

That the diatom frustules produced in the winter and spring months quickly settle through the water was evidenced by repeated measurements of the amount of diatom remains in the water at depths of 1000 meters or more. In October, when the surface waters were bare of phytoplankton, practically no diatom remains were found in the deep water; after plankton production had proceeded for a few weeks near the surface, it was possible to collect many thousands of diatom frustules per liter even at depths greater than 1000 meters.

Large-scale phytoplankton production and huge diatom populations occur elsewhere, off the American west coast, for example, yet the bottom deposits are not notably diatomaceous because the frustules settling into deep water become dispersed and dissolve before reaching the bottom. In the last analysis, the rate of silica deposition on the bottom must be exactly equal to the excess of silica brought into any region over that carried out of it by water movements. From this point of view, the formation of siliceous deposits on the floor of the Gulf must be due essentially to the character of the circulation, and the presence of these deposits can be taken as evidence that silica-rich water flows into the Gulf at depth and that silica-poor water leaves it at the surface. This is confirmed by the observed increase in concentration of silica in the deep water from the mouth of the Gulf to the region west of Guaymas and by the fact that the deep waters of the Gulf have about 30 percent more silica per unit of volume than do those of the open sea.

ECOLOGY OF SULPHATE-REDUCING BACTERIA IN MARINE SEDIMENTS

It is well known that in many oil field waters there is little or no dissolved sulphate ion, even when the chloride content is high. Since these waters usually represent in part fossil sea water trapped in the interstices of marine sediments, the observed absence of sulphate must mean that this substance has been removed from the waters after deposition. Likewise in Recent marine deposits the interstitial waters are often deficient in sulphate but instead contain either hydrogen or black iron sulphide. The removal of sulphate and the production of sulphide can be shown to be due to the action of anaerobic sulphate-reducing bacteria, which utilize the oxygen in the SO_4^{--} radicle for the combustion of organic matter and thereby gain energy for their life-processes. Many large sulphur deposits are believed to have originated through the bacterial reduction of sulphates in shallow marine lagoons. These bacteria also play an important role in determining the hydrogen-ion concentration, the oxidation-reduction potential, and other physico-chemical conditions in marine sediments and thus they may be of fundamental importance in diagenesis.

Rittenberg, working under the general supervision of Dr. C. E. Zobell, has recently carried out an extensive ecological investigation of marine sulphate-reducing bacteria in sediments off southern California and in the Gulf of California. 450 individual core and dredge samples from 160 localities were tested for the presence of these organisms by the technique of enrichment cultures. The cultures were prepared on ship-board immediately after the collection of the samples, and aseptic technique was used throughout. It was found that although sulphate-reducing bacteria are widely distributed in marine deposits, they are most abundant in the surface layers of the sediments and decrease rapidly both in numbers and activity with depth below the surface. In many instances, practically complete removal of all the sulphate had occurred only a few feet below the deposit surface. The data thus indicate that reduction of sulphate, either bacteriologically or chemically, does not occur in deeply buried oil-bearing strata, as postulated by many writers but that instead it takes place shortly after deposition.

When the samples in which sulphate reducers were demonstrated are tabulated against particle size it is immediately seen that viable organisms are most common in the coarse sediments and decrease in number with decreasing particle size. This distribution is exactly opposite to that of other bacteria or of the organic matter on which the micro-organisms subsist. Most of the coarse sediments came from shallow inshore waters where the rate of deposition (but not of accumulation) is presumably much faster than that of fine sediments in deep water. It may be that because of more rapid burial, the organic matter in coarse deposits has a different composition when it reaches the anaerobic environment than the organic matter of more slowly deposited sediments, which is exposed for a longer time to decomposition at the bottom surface. The organic matter of sandy and silty muds may thus be more favorable to the needs of sulphate-reducing bacteria. It is significant that on the open California sea-floor, black muds containing iron sulphide are found in shallow-water environments of rapid deposition, while H_2S alone is found in deeper, more slowly laid down deposits. Neither sulphate-reduction nor sulphate-reducing organisms were observed in pelagic sediments.

In a core of laminated, diatomaceous mud where the rate of deposition could be calculated by counting the laminae in a measured length of the sample, it was possible to arrive at the rate of hydrogen sulphide production. A maximum rate of .35 mg H_2S per liter per year was computed, corresponding to a maximum free energy available to the bacteria of .0715 cal. per liter per year, and to a total sulphate-reducing population at any given time of 55 cells per ml. of interstitial water. The slow rate of reduction in this core probably is due to the low temperature (6° C) of the bottom waters. In Monterey Bay, where the observed bottom temperature was 11°, an apparently much higher rate of reduction was observed.

STUDIES OF THE DISTRIBUTION OF RECENT FORAMINIFERA OFF CENTRAL AMERICA AND IN THE GULF OF CALIFORNIA

Many of the cores of bottom sediments collected on the two E.W. Scripps expeditions to the Gulf of California have been examined by Natland. In addition, the Foraminifera in 170 samples collected by ships of the U. S. Navy and the Coast and Geodetic Survey from off Panama and Costa Rica have been studied by him. The latter samples were collected at depths ranging from one to 4140 meters but they were not obtained along a straight line ranging from shore to deep water. On the contrary, the locations are scattered to form a grid under the coastal waters from the Bay of Panama to the Gulf of Nicoya, and consequently a great variety of environments is represented.

The relative abundance of the 400 species present in the samples from Panama and Costa Rica has been determined and plotted graphically to show the bathymetric range of each species. Certain Foraminifera off Central America, as off southern California [1] have limited depth ranges and are grouped into definite zones. A comparison of the depth ranges of these species, and of zones off southern California and Central America, follows:

Zone I (lagoonal):- No samples were collected from strictly lagoonal environments off Central America, but judging from the fauna present in one meter of water at Point Burja in the Bay of Panama, it is fairly safe to say that the lagoonal fauna in this region differs but slightly from that found in southern California, where the species characteristic of lagoonal areas are Trochammina inflata Montagu and abundant Rotalia beccarii (Linné). Off Central America, R. beccarii is abundant down to 100 meters, and in one location down to 400 meters. It is probable, however, that those present at 400 meters were brought down from shallower waters by currents or by slumping. The fact that the temperature (14-16° C.) at 100 meters off Central America is approximately the same as the winter temperature in lagoons off southern California (15°, March 3, 1941) suggests that the distribution of R. beccarii on the sea floor is controlled by an isotherm and not by a depth contour. The opposite seems to be true of T. inflata, for in both areas it is confined to lagoonal or near-lagoonal environments in less than 5 meters of water.

1/ M. L. Natland, The temperature and depth distribution of some Recent and fossil Foraminifera in the Southern California region. Bull. Scripps Institution of Oceanography. Techn. Ser., Vol. 3, no. 12, 1933.

Zone II (0-40 meters off southern California):- Elphidium spinatum Cushman and Valentine is the species most characteristic of zone II off southern California, where it ranges in depth from shore to 40 meters. Off Central America, E. spinatum is abundant from 0 to 30 meters and is rare from 30 to 46 meters. Below 46 meters only occasional specimens are found even in large faunas and these may be out of place. The vertical ranges in both regions are so similar as to indicate that depth or some function of depth, controls the distribution of this species. Other forms, such as Nonion scapha (Fichtel and Moll) and Buliminella elegantissima d'Orbigny extend into deeper water off Central America than off southern California, suggesting that temperature has a greater influence on their lives than depth.

Zone III (40-275 meters off southern California):- The fauna present in zone III, from 40 to 275 meters off southern California, is made up chiefly of species of Cassidulina, including C. tortuosa Cushman and Hughes, C. limbata Cushman and Hughes, and C. californica Cushman and Hughes. These species have not been found off Central America, where instead of the Cassidulinidae, the Bulimidae predominate. The principal species in zone III off Central America are Bolivina advena var. striatella Cushman, Bolivina subadvena var. serrata Natland, Bolivina vaughani Natland, Bulimina pulchella d'Orbigny, Virgulina bramletti Galloway and Morrey, Virgulina sp., Loxostoma cf. mayori Cushman, Uvigerina cf. tenuistriata Reuss, and Angulogerina sp.

The boundary between the zone III Cassidulinid province off southern California and the Buliminid province of the same depth range off Central America is probably near the northern end of the Gulf of California. In bottom samples collected by the E. W. Scripps, a typical Central American fauna was found on the east side of the Gulf, while a good southern California fauna was obtained from the west side. It is well known that a marked difference in molluscan faunas exists on the two shores of the Gulf, pearl oysters for example occurring only on the western side. Whatever the nature of the faunal barrier, it is not effective to depths below the range of the zone III fauna for the foraminiferal assemblage at greater depths is practically the same in both regions.

Zone IV (275-ca. 1800 meters off southern California):- At a depth of about 275 meters off southern California there is a profound faunal change. Approximately 50 species appear for the first time and a like number disappear near this depth. Off Central America, many forms such as Cassidulina cushmani Stewart and Stewart, Bolivina pseudobeyrichi Cushman and Epistomina elegans (d'Orbigny) also begin at 275 meters, while others including Bolivina subadvena var. spissa Cushman, Bolivina argentea Cushman, Uvigerina perigrina Cushman and Pulvinulinella pacifica Cushman follow the 8° isotherm, which is 190 meters deeper off Central America than it is off southern California. Here again the

evidence indicates that depth and temperature are independent ecologic factors.

Because of the large number of samples from zone IV off Central America, it is possible to divide this zone into two parts. The boundary may be placed near 900 meters, where Eponides subtenera (Galloway and Wissler), Pullenia bulloides (d'Orbigny), Martinatiella communis var. pallida (Cushman), Uvigerina cf. ampullacea Brady, and Bulimina subacuminata Stewart and Stewart first appear; and Angulogerina carinata Cushman and Uvigerina sp. drop out.

In the upper part of zone IV there are found several species in the Central American region which do not occur off southern California. However, in the lower part of zone IV, the faunas in both areas are practically identical.

Zone V (Deeper than about 1800 meters off southern California):- Off southern California an insufficient number of samples has been studied to determine the upper limit of the zone V fauna. In the Central American region more samples have been available and the top of the zone may be placed at 1750 meters, where Bulimina rostrata Brady becomes abundant. This species and its characteristic associates are present even in the deepest samples at 4140 meters, and they may extend to a far greater depth. Nonion umbilicatula (Montagu) was not found in samples shallower than 2500 meters off Central America, and likewise off southern California only two samples, both deeper than 2500 meters, contained this form.

Relative importance of different ecologic factors:- Some of the above data suggest that the distribution of certain foraminiferal species is controlled by temperature, while that of others is determined by a function of depth. Ordinarily in a given region the bottom temperature at any depth below the upper one or two hundred meters is virtually uniform, or in other words, the isothermal surfaces at the bottom are nearly level. Consequently it is difficult to separate the effects of temperature and depth upon foraminiferal faunas. This separation can be made, however, and the relative importance of depth, temperature, and possibly light and food supply can be evaluated by a comparative study of sections from different latitudes. Another promising method is to examine faunas from depressions with shallow sills, where regardless of depth the temperature on the bottom is close to that at the deepest entrance to the depression. The Ballenas Trough in the Gulf of California is an excellent example. Here a temperature between 11 and 12°C is present at the threshold depth of about 350 meters. On the bottom of the Trough, at about 1500 meters, the temperature is over 11°, while in the open Gulf, outside the closed depression, the temperature at 1500 meters is close to 4°. Although many of the species present in the bottom of the Trough usually live at depths shallower than 300 meters, the fauna is largely composed of species which tolerate

a wide range of depth and temperature. Of 32 species identified in a mud sample from the floor of the depression, 16, or 50%, were obtained from both deep and shallow water in the nearby Gulf, while such wide-ranging forms make up only 27% of the normal fauna of the Gulf floor. 47% of the species in the Trough sample were found solely at depths of 300 meters or less outside the depression, and only one form occurring in the sample, Nonion punctata, is a strictly deep water organism.

Difficulty of recognizing redeposited forms:- The Los Angeles and Ventura basins in southern California were formerly deep-water basins which during the Pliocene and Pleistocene gradually filled with marine sediments containing an abundance of Foraminifera. Except for an extinction of about 5% of the species found in the lower Pliocene, the fossil faunas are the same as those living today in the sea off southern California. Studies by micropaleontologists of numerous surface and well sections from these basins have furnished as nearly complete a knowledge of the relative depth ranges of many species as have sections from the adjacent sea floor. Actually, since the sea floor contains numerous outcrops of fossil sediments, a full understanding of the recent section cannot be obtained without a rather complete knowledge of the fossil ones. Undoubtedly, many occurrences of Recent species given in the literature represent redeposited forms, and consequently considerable doubt exists as to the published bathymetric ranges of many species. The most difficult task for one attempting an ecologic study of Recent Foraminifera is that of determining which species are autochthonous.

ECOLOGY OF CORALS AND MOLLUSCS IN THE GULF OF CALIFORNIA

Dr. J. Wyatt Durham, one of the members of the E. W. Scripps expedition to the Gulf of California in 1940, made extensive collections of Recent mollusks and corals for purposes of comparison with the Pliocene and Pleistocene occurrences on the west side of the Gulf. He has submitted the following notes with regard to the distribution of certain coral forms.

> "Porites ranges at least as far north as 28°30' north latitude, where a head over 18 inches in diameter was collected.
>
> Stephanaria cf. stellata Verrill has its northern limit of range at about 26° north latitude.
>
> Pocillipora does not appear to extend as far north as Stephanaria.
>
> Among the deeper water corals, Balanophyllia appears to live in deeper water than Astrangia."

ECOLOGICAL STUDIES OF THE FORAMINIFERA

by

Earl Hamlet Myers

PROBLEMS

The object of this work was to study the influence of zonal conditions in the sea in relation to distribution, test morphology, and life histories of Foraminifera. The methods used made it essential that the significance of polymorphism and the sequence of these stages in the life cycle of certain species be conclusively determined. It was then necessary to consider the influence of measurable ecological conditions upon growth, life span, and the rate of reproduction; and finally to interpret the distribution of species and their productivity in major and minor regions where only limited information was available concerning chemical and physical conditions in the sea.

FOOD CYCLE OF FORAMINIFERA

From cytoplasmic inclusions and culture experiments it seems obvious that many Foraminifera living in or immediately below the photic zone utilize plant cells as food, and although they readily accept and digest bits of animal tissue they are unable to capture organisms capable of vigorous movement. Therefore it is probable that the food of Foraminifera living below the photic zone is made up of saprophitic organisms including bacteria and the substratum upon which they live which consists of plant and animal detritus that had its origin near the surface of the sea. In the higher latitudes variations in the productivity of photosynthetic organisms follows the zenith position of the sun, therefore this source of animal food becomes most abundant in the spring when the sea water is rich in nutrient salts. Later these organisms are greatly reduced in numbers by the grazing of plankton herbivores and the depletion of soluble nitrates and phosphates. These phytoplankton organisms again become numerous for brief intervals during the summer whenever a supply of nutrient salts becomes available. In the fall turbulence caused by storms results in mixing of the nutrient-deficient surface water with the richer deeper water, and a brief outburst of phytoplankton results that is soon terminated by the decreasing hours of sunlight. Winter is a period of comparative dormancy. Plankton herbivores become most numerous following the spring outburst of phytoplankton, are gradually reduced in numbers through the late summer and fall and are at a minimum throughout the winter. The influence of this cyclical distribution of plankton organisms, especially the phytoplankton, has a marked influence on growth and reproduction in the Foraminifera.

GROWTH AND REPRODUCTION IN THE FORAMINIFERA

Growth in most species of Foraminifera is accomplished by the addition of one chamber at a time to the developing test to form a graduated series. No growth occurs during the winter, and the weakened condition of the individuals frequently encourages parasitism. With the spring outburst of phytoplankton there is a noticeable change in the physical state of the cytoplasm and after the addition of several chambers in quick succession the individual usually reproduces in one of two ways. Microspheric individuals asexually produce megalospheric juveniles which are provided with two or three chambers before leaving the vicinity of the parent test, while megalospheric individuals usually produce flagellated gametes which unite in fertilization with gametes derived from a second megalospheric individual. In certain larger species in which brood chambers are formed, megalospheric as well as microspheric individuals are multinucleate, and the presence of brood chambers containing megalospheric juveniles makes it evident that at least in these species one or more asexually produced generations may succeed sexual reproduction. Other species seem capable of continued existence without an intervening sexual phase in the life cycle. When Foraminifera are killed and hardened in a hot aqueous solution of formaldehyde and the test dissolved in weakly acidified strong alcohol it is possible to determine the number of chambers and to note evidence of reproduction.

LIFE SPAN OF THE FORAMINIFERA

Chamber counts in samples of from five hundred to one thousand individuals, taken at one month intervals for a period of one year plotted as percentage frequency distribution curves, make it possible to determine the rate of growth, the time and rate of reproduction and the probable rate of survival. This evidence supplemented by data obtained from cultures maintained under controlled conditions indicates that the life span of Foraminifera found in the shallow waters of the temperate zone ranges from a few days in the smallest species to one or even two years in larger forms. In temperate latitudes the life cycle of Elphidium crispum Linn. including a sexual and an asexual phase was found to require at least two years. Under tropical conditions where the source of food organisms is relatively constant but never abundant, the rate of growth is less than that observed during the spring outburst of phytoplankton in higher latitudes, resulting in the life span being reduced by about one half and the life cycle repeated at intervals of one instead of two years.

ECOLOGICAL STUDIES IN THE JAVA SEA

In our survey of the Java Sea, samples were taken at about one degree intervals throughout the area and along adjacent coasts and in the vicinity of all important groups of islands. In this region the monsoon winds and the changing zenith position of the sun results in variations with two maxima, but the amplitude of these changes are negligible except in coastal waters where the salinity is depressed and the nutrient salt content of the sea water increased by water brought in by large rivers, and at the entrances of the sea especially to the east and through Sunda Strait where colder water of higher salinity enters the region. The amplitude of temperature differences over much of the area ranges from 26 to 28° C, the salinity from 32.5 to 34.5% and the depth from thirty to fifty meters. Since it is possible to overlook these usually important factors, the problem of accounting for zonation in populations of Foraminifera is greatly simplified. The distribution of the tests of pelagic Foraminifera in the sediments is in agreement with more recent ideas of circulation. These bathypelagic Foraminifera, which as the term suggests have their origin in the deeper parts of the ocean, enter this shallow sea but do not thrive in the new environment; therefore water from the South China Sea, where conditions are not unlike those found in the Java Sea where Globigerina is rare, is driven into the area by west monsoons. Water from the Flores Sea which moves over the Sunda Shelf during the east monsoons is more typically oceanic and as a result specimens of Globigerina are numerous in the sediments in the eastern half of the Java Sea. To the east of Sunda Strait along the coast of Java they are found in the sediments as far east as the Bay of Batavia, suggesting the degree to which deeper currents from the Indian Ocean enter this region. Sediments in the great central basin and the region along the west coast of Sumatra are mainly light gray muds often containing a large percent of colloidal material. Conspicuous zonal types in this major region include Rotalia papillosa, Elphidium macella, Rotalia calcar, and Operculina. In sandy mud areas about the scattered islands in the southern half of the Java Sea Heterostegina, Operculinella, and Alveolinella are common, and where there is an abundant macroflora Baculogypsina is also abundant. In the north-east and north-west portions of the Java Sea under conditions which are superficially similar to those described above these species were not observed. Living on the macroflora that is usually present immediately inside the zone of living corals in reef areas several species of Calcarina, Peneroplis, Elphidium, Amphistegina and Amphisorus were common, and although the tests of many of these species occur in the sediments adjacent to these reef areas most of them do not thrive except where there is a heavy growth of macroflora. In the completed work much attention will be paid to ecological associations in major and minor areas and the way in which the tests of Foraminifera are modified to meet the requirements of particular habitats.

FORAMINIFERAL POPULATIONS ON THE FLOOR OF THE SEA

Populations per unit area which are dependent upon the available food supply, the nature of the bottom, and other factors were determined from samples taken with the aid of a special suction grab sampler. This instrument was so constructed that a sample of surface sediments four inches in diameter was drawn into a closed cylinder so as to preclude the chance of loss through washing. Finer sediments were removed with the aid of a sieve, the bottom of which was a piece of no. 25 bolting silk. The sample was then treated with a ten percent hot aqueous solution of formaldehyde. A portion of the sample was sorted, decalcified and the protoplasmic casts stained with biological stains to determine the number of living Foraminifera. It is necessary to use caution in this work since in many regions the tests become filled with mineral substances which result in the casts that closely resemble the protoplasmic elements of living Foraminifera. It was found that the number of Foraminifera per sample varied from a few to thousands, while in one region living Tinoporous were found to exceed one hundred thousand individuals per square foot.

Over much of the area, salinity determinations, temperatures, and Secchi disc readings were made for all seasons and before the work is completed it is hoped that chemical data will become available.

In certain areas many of the empty tests were completely filled with finely crystalline aluminum silicate, in other regions iron pyrites, usually in the form of minute spherules, filled the chambers, and in one region glauconitic casts were common. It is hoped that much may be learned from the work now in progress concerning the way in which these substances enter the tests of Foraminifera.

This work on the ecology of the Foraminifera was begun at the Scripps Institution of Oceanography of La Jolla, California, was continued for one year under a John Simon Guggenheim Memorial Foundation Fellowship at Plymouth, England, and for a second year along the south coast of France and in the area about Singapore. A Rhumphius Fellowship granted by the Treub Laboratories of the Netherlands East Indies made it possible to extend the work to include a survey of the Java Sea and to study ecological conditions in this tropical region under unusually favorable conditions.

RECENT STUDIES OF THE ECOLOGY OF CORALS

by

T. Wayland Vaughan

PALEOZOIC BIOHERMS

Two papers are as follows:

Lecompte, M., Quelques types de "récifs" siluriens et dévoniens de l'Amérique du Nord. Essai de comparaison avec les récifs coralliens actuels: Mus. roy. d'Hist. nat. de Belgique, Bull., vol. 14, no. 39, pp. 51, 5 pls., 7 figs., Sept., 1938.

Shrock, R. H., Wisconsin Silurian bioherms (organic reefs): Geol. Soc. Amer. Bull., vol. 50, pp. 529-562, 2 pls., 4 figs., April, 1939.

The scope of the first paper is indicated by its compound title. It attempts a review of some of the better known Paleozoic bioherms of New York, Indiana, and Michigan, based upon field studies. This is followed by a summary of the conditions under which modern reefs form and a comparison of the Paleozoic bioherms with modern reefs. The conclusions are that the conditions of formation of the Paleozoic bioherms were different from those of the formation of modern reefs. Although this paper is thoughtful and possesses valuable features, it is obvious that the author has not assembled or digested large bodies of available information on the initiation and structure of modern and Pleistocene reefs. Many of the opinions expressed do not accord with those of the second paper listed. Two of Shrock's conclusions are (a) the bottoms surrounding the bioherms "were built up slowly from the fine calcareous materials produced by erosion of the growing bioherms or as precipitates from overlying water," and (b) "the horizontal beds upon approaching a bioherm gently rise toward it with increasing dips, and often with increasing thickness, until they lose their identity through transition into the core rock. This relation suggests that the growing bioherms were surrounded by talus deposits of clastic calcareous sands, in which the stratification developed quaquaversally from the biohermal mound."

MODERN REEFS AND DEEP-SEA CORALS

Pelew Islands.- For several years the Japanese have been active in the study of numerous aspects of the reef coral faunas of the Pelew Islands, called by them Palao Islands. The ten following papers published by them during 1939 and 1940 deserve mention:

Motoda, S., Submarine illumination, silt content and quantity of food plankton of reef corals in Iwayama Bay, Palao: Palao Trop. Biol. Sta. Studies, vol. 1, no. 4, pp. 637-649, 2 figs., 6 tables, Sept., 1939.

Abe, N., On the expansion and contraction of the polyp of a reef-coral, Caulastraea furcata Dana: Ibid., pp. 651-669, 5 figs.

_____, Migration and righting reaction of the coral, Fungia actiniformis var. palawensis Doderlein: Ibid., pp. 671-694, 9 figs.

Motoda, S., A study of the growth rate in the massive reef coral Goniastrea aspera Verrill: Palao Trop. Biol. Sta. Studies, vol. 2, no. 1, pp. 1-6, 1 fig., 3 tables, July, 1940.

_____, Comparison of the conditions of water in the bay, lagoon, and open sea in Palao: Ibid., pp. 7-28, 2 figs., 1 table.

Hosoi, K., Contribution to the biochemistry of the coral. IV. Iodine in the polyp of Fungia actiniformis var. palawensis Döderlein: Ibid., pp. 49-50.

_____, Contribution to the biochemistry of the coral. V. Distribution of nitrogen in the protein of the polyp of Fungia actiniformis var. palawensis Döderlein: Ibid., pp. 51-55, 2 tables.

_____, Contribution to the biochemistry of the coral. VI. Calcium and carbonate in the skeleton of Fungia actiniformis var palawensis Döderlein: Ibid., pp. 57-59, 4 tables.

Motoda, S., The environment and the life of the massive coral, Goniastrea aspera Verrill, inhabiting the reef flat in Palao: Ibid., pp. 61-104, 9 figs., 13 tables.

Abe, N., Growth of Fungia actiniformis var. palawensis Döderlein and its environmental conditions: Ibid., pp. 105-145, 11 figs.

To present abstracts of these papers would make this statement too long. The titles indicate the subjects considered. There is much valuable information.

Siro Kawaguti (in English Shiro Kawaguchi) of the Taihoku (Formosa) Imperial University has published in English one article, "An abundance of reef-coral planulae in plankton": Zool. Mag. (Tokyo), vol. 32, no. 1, p. 31, 1940.

On July 3, 1939, clouds of planulae were observed at Suoo on the east coast of Formosa.

Kawaguchi has published in Japanese in the journal "Kagaku Nanyo", no. 2, vol. 3, 1940, nine notes on reef corals. The subjects in English are as follows:

1. The skeletons of reef-corals and Zooxanthellae.
2. Light in relation to the form of reef-corals.
3. Natural death of Fungia repanda.
4. Air bubbles from broken branches of reef-corals.
5. Stinging reef-corals.
6. Larvae of Acropora and Acrhelia.
7. Influence of fresh water on reef-corals.
8. Correlation between colonies and individuals in reef-corals.
9. Redox-potential in reef-corals.

Tahiti.- The following paper is pertinent in this connection:

Crossland, C., Further notes on the Tahitian barrier reef and lagoons: Linn. Soc. (London), Jour., Zool., vol. 40, pp. 459-474, pls. 12, 13, sketch-map, Jan., 1939.

There is a discussion of Lithothamnioneae and a continuation of the history of the changes in the fauna and flora of lagoon reefs due to the flood of January, 1926.

Java.- The following is an important paper:

Umbgrove, J. H. F., Madreporaria from the Bay of Batavia: Leiden Museum Zool. Med., vol. 22, pp. 64, 18 pls., 4 figs., 1939.

Two sections of this memoir are entitled, respectively, "Structure of reefs and islands" (pp. 3-5), and "Ecology of the reefs; facies-types." The facies-types recognized are 1. Montipora ramosa facies; 2. Rhodophyceae facies; 3. Montipora foliosa facies; 4. Thriving reef; 5. Shingle ramparts; 6. Impoverished reef facies. Fig. 4 presents a map of the principal facies and other features, and fig. 3 is a block diagram to show structure. Notes on the habitats of the different species are given in the systematic part of the paper, which is an unusually fine scientific contribution.

Australia.- The paper next to be mentioned is outstanding.

Yonge, C. M., The biology of reef-building corals: Brit. Mus. (N.H.), Grt. Barr. Reef Exped. 1928-29, Sci. Repts., vol. 1, no. 13, pp. 353-389, 6 pls., 1940. Appendix, "A note on the appearance of living coral polyps by Prof. T. A. Stephenson, pp. 389-391.

This paper presents a summary of virtually all available information on the ecology of modern reef-building corals, incorporating the results of the studies of the Great Barrier Reef Expedition of 1928-29. The contents are as follows:

1. Introduction.
2. Characteristics of coral reefs.
3. Nutrition.
4. Adaptations of reef-building corals
   (a) Adaptations for feeding.
   (b) Form of the skeleton in relation to water movements.
   (c) Effect of sediment.
   (d) Adaptations to shore conditions.
5. Significance of the Zooxanthellae.
6. The effect of light on coral growth.
7. Reproduction and development.
8. Growth of corals.
9. Maintenance of reefs.
10. The form of coral reefs.
11. Distribution of reef-building corals.
12. Evolution of reef-building corals.
13. Summary.
14. References.

Much of the discussion confirms opinions or expands the basis of opinions already held; but the section "Reproduction and development" presents a first treatment of an important aspect of the biology of corals, the relation between temperature and the spawning of corals, and the effect of the spawning temperature range on horizontal distribution.

Indian Ocean.- The titles of three papers are as follows:

Gardiner, J. Stanley, and Waugh, Peggy, The Flabellid and Turbinolid corals: Brit. Mus. (N.H.), The John Murray Exped. 1933-34, Sci. Repts., vol. 5, no. 7, pp. 167-202, 7 pls., 6 figs., 1938.

_____, Madreporaria excluding Flabellidae and Turbinolidae: Ibid., vol. 6, no. 5, pp. 225-242, 2 pls., 3 figs., 1939.

Gardiner, J. Stanley, The ecology of solitary corals: Ibid., vol. 6, no. 5, pp. 243-250, 1939.

These papers have very small value for the study of the ecology of corals. No temperatures are given in either of the papers by Gardiner and Waugh, and there is virtually no discussion of temperature relations in the third paper. By using the station list for H.E.M.S.

"Mabahiss" in the Indian Ocean it has been possible to supply some of the needed data.

Red Sea.- A single paper will be mentioned:

Crossland, C., The coral reefs at Ghardaqa, Red Sea: Zool. Soc. London, Proc., ser. A, vol. 108, pp. 513-523, 3 figs., Feb. 10, 1939.

This article contains interesting details regarding the reefs at Ghardaqa. It supplements other previously published papers.

Eastern Pacific Ocean.- The following paper is in press:

Vaughan, T. W., New corals: one Recent, Alaska; three Eocene, Alabama and Louisiana: Jour. Paleontology, vol. 15, pp. 280-284, pls. 40, 41, May, 1941.

A single species of Caryophyllia, C. alaskensis Vaughan, n. sp., is described from two stations in Alaskan waters: "Albatross" sta. 4231, vicinity of Naha Bay, Behm Canal, southeast Alaska; depth 150 to 208 m; temperature 6.1° C. (a subpolar temperature); and "Albatross" sta. 4300, off Shakan, Summer Strait, southeast Alaska; depth 338 to 399 m; temperature not recorded but probably lower than 6.0° C. The same or a very similar species occurs in the coastal waters of British Columbia, where it is associated with Balanophyllia elegans Verrill.

One of the pressing desiderata in the study of modern corals is a monographic treatment of all coral faunas, both deep-water and shallow-water, for the entire eastern Pacific Ocean. Considerable collections, with ecologic data, for such a study are available at the U. S. National Museum and the Scripps Institution of Oceanography, and there may also be material at Stanford University and other places. The study is not a very large job, but it would require a year or two for its completion.

Mr. J. Wyatt Durham of the Museum of Paleontology, University of California at Berkeley, contemplates describing the living coral fauna of the Gulf of California, utilizing material recently collected on the expedition conducted under the joint auspices of the Scrips Institution of Oceanography and the Geological Society of America.

GENERAL

The following paper is pertinent in this connection:

Vaughan, T. W., Ecology of modern marine organisms with reference to paleogeography: Geol. Soc. Amer. Bull., vol. 51, pp. 433-468, 8 figs., March, 1940. Pages 458-464 are devoted to a brief statement of some of the ecologic relations of corals.

T. W. Vaughan and J. W. Wells have transmitted to the Geological Society of America a large manuscript entitled "Revision of the suborders, families, and genera of the Scleractiniae (stony hexacorals)." One section of this work is devoted to ecology. The treatment is intended to be more extensive than the excellent paper by Yonge considered on a previous page of these notes, but in one respect at least it is unsatisfactory. Most of the describers of the species of ahermatypic, chiefly deep-sea, corals have treated the oceans as if they were bodies of water of uniform temperature and composition throughout, but of horizontal extent and of varying depth. There are few endeavors to ascertain any fundamental relation between the organisms and the different features of the water masses in which the organisms live. An attempt has been made to assemble records of bottom temperatures from station lists and oceanographic reports and thereby find out the temperatures at which the different species live.